ROMAN FEVER

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THE RESULTS OF AN INQUIRY DURING THREE YEARS' RESIDENCE ON THE SPOT INTO THE ORIGIN, HISTORY, DISTRIBUTION AND NATURE

OF THE

MALARIAL FEVERS

OF THE

ROMAN CAMPAGNA

WITH ESPECIAL REFERENCE TO THEIR SUPPOSED CONNECTION WITH PATHOGENIC ORGANISMS

BY

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PREFACE

THE author was appointed in the year 1883, to one of the Research Scholarships in Sanitary Science of the Grocers' Company of the City of London, and in that capacity went out to Italy, with the object of making full inquiry into the nature and origin of the disease known as "Roman Fever," a local form of a malady widely prevalent elsewhere, and especially interesting to Englishmen, as it cripples and weakens a large proportion of those who are, in distant parts of the world, engaged in extending and consolidating our Colonial Empire.

The extent of the task was not at first apparent, but before the end of the year for which the Scholarship was held it became so. It was then seen that the work of a period so limited could suffice only to make more or less visible the lines on which any useful inquiry would have to be made. Accordingly the appointment was renewed and the work continued and much of it accomplished. A second renewal enabled the author to give two full years to the filling up of the outline his first year's work had enabled him to draw.

The author's original intention was to devote himself to a special study of the supposed relation of malarial fevers to pathogenic organisms. Very early in the inquiry, however,

it became obvious to him that the distribution of the disease presented peculiarities which demanded a more thorough investigation, and to this end a large number of localities known to be specially affected by the disease were carefully examined as to soil, drainage, and general local conditions, in order to determine what, if any, were the invariable characteristics of the malarious districts of the Campagna, and also to define the conditions to which it was apparently necessary that a person should be exposed in order to acquire the disease.

It became clear as the result of these preliminary investigations, that an intimate relation existed between the malady and the quantity and distribution of the subsoil water; and that differences, even small, of altitude and position, and variations of temperature, regarded as strictly local conditions, were also of considerable weight.

A series of careful observations was then made of the exact variations of temperature, of the subsoil and atmospheric moisture, and of the altitude, in each of several peculiarly unhealthy areas, the result of which was to demonstrate the purely local character of these factors, and an obvious connection of them with the disease. There was also found to be considerable constancy in the association of a certain local distribution of the water in the subsoil with the abnormal meteorological conditions observed on the same spot, and a more or less obvious connection with a like local liability of the inhabitants to the disease. The author finally made a similar examination of the apparent local results of cultivation, of drainage works, and of the presence or absence of trees in various parts of the Campagna, and also of the local condition of the inhabitants.

These researches taken with a simultaneous study of the history and progress of malaria in the Province of Rome, so

far as it has been recorded down to the present time, have led to the following conclusions :—

1. That in the Roman Campagna, waterlogging of the subsoil and the peculiar meteorological conditions which, commonly, if not invariably, result from it in warm climates, is the most important factor in the production of the disease.

2. That the well known diminution of intensity of the disease, which occurs with increasing altitude, is in a great measure (if not entirely) to be explained by the effect of the coincident difference of level on the distribution of the subsoil water, and a corresponding change in the meteorological conditions resulting from that distribution.

3. That in the Roman Campagna, and probably in all temperate and subtropical climates, the disease is not found, except where the conditions above referred to are present.

4. That an excess of water in the subsoil, though when present it aids in the production of the disease, will not alone produce it.

5. That it is not absolutely necessary to its production.

6. That the only condition constantly present is sudden and excessive change of temperature, most commonly due to great radiation, especially at sunset and sunrise. The common experience of the inhabitants of all malarious countries proves this to be dangerous, and the present inquiry has for its chief result an intelligible confirmation of this experience.

That the state of the atmosphere, as regards its heat and moisture, is intimately related to the distribution of the disease there seems to be no room for doubt. Whether these conditions are in themselves sufficient to produce the disease, or only favour the growth of some pathogenic organism, which, on entering the body, is capable of producing it, is a further question.

To some probably the latter would be the more acceptable

hypothesis. To these however the author would suggest that in the case of intermittent fever, the extraordinary varieties in the period of incubation, extending from days even to years, the liability to recurrence after exceedingly long periods of rest, the occurrence of the peculiar phenomena of intermittence in the case of other febrile disorders, when these attack persons who even long before have suffered from ague, the nature of the remedies commonly used and the precautions universally admitted to be expedient in order to avoid the disease, all present serious difficulties to any course of reasoning which could lead us to adopt such a theory.

With our present knowledge of the facts it would seem that the only alternative is to recognise in Malarial Fever a purely nervous disorder, a breakdown of the heat-controlling mechanism of the body under severe strain; this also would account for the disease without having recourse to the hypothesis of the invasion of a pathogenic organism.

The evidence in this direction, however, is not convincing, but it is too strong to be summarily rejected, and it appears to receive some support from the facts detailed in the present work. On the other hand, the advocates of a special pathogenic organism have much to say that is worthy of careful consideration. Our knowledge of the changes in the blood corpuscles during an attack of ague has been greatly advanced by the labours of French and Italian students in this field, and notably by the researches of Laveran, Celli, and Marchiafava. They claim to have detected a specific organism capable of destroying the red corpuscles and of producing changes in their structure alone sufficient to account for the disease.

But valuable as these researches undoubtedly are, they cannot, in the author's opinion, as yet be regarded as account-

ing for the origin and maintenance of the Malarial Fever as we now know it.

The horizontal and vertical distribution of Malaria is so peculiar and so very difficult to account for on the hypothesis of any organic cause, that we must at least suspend our judgment until this hypothesis is supported by clearer and more direct evidence.

The author must indeed confess that while his acquaintance with this subject was limited to what he could learn from the researches of others, he was deeply impressed with the evidence in favour of the origin of malarial fevers in a micro-organism. This impression was first shaken by personal experience of the disease itself, and afterwards by minute and continuous observation of the circumstances and localities in which it may be acquired.

In this direction undoubtedly there is still much to be done, but the author has good hope that what he has been enabled to do will tend materially to reduce the labour, and also to give additional certainty to the conclusions of those who may follow him in the investigation, the results of which are here stated.

Enough has already been ascertained to give a definite direction, and some degree of precision to the methods to be adopted in any particular case for ridding a locality of the disease or protecting its inhabitants from the consequences of its invasion. The aspect of the inquiry here presented, as becomes its purpose, is rather sanitary than pathological. It is directed to practical issues rather than to theoretical conclusions, but the author trusts that the information collected will in either direction be found interesting and useful.

The headings of chapters, which are appended, will show the order in which the results of the inquiry are stated, and give some idea of the general scope of the work. The author

has become painfully aware that it is one thing to discover and register facts, to make out their relation to each other, to place them in logical sequence so as to deduce from them sound conclusions, and another to give them, when thus correlated, the literary expression needed to convey these conclusions clearly to a reader to whom the facts are new, and still more difficult to give to the general results of such an inquiry the precision and force required to overcome prepossessions in favour of prior and already prevalent opinions.

Also he has learned that in science novelty alone has no legitimate charm, and accordingly the newness of a fact or the strangeness of an inference has only prompted him to additional care in its acceptance.

He was sent to inquire and to state what he learned. This, and this only, he has tried to do, and when he regards the subject on the one hand, and his own powers on the other, he feels that he can at most have made but a small, though perhaps a fruitful, contribution to our knowledge of a matter of great and world-wide importance.

The author's thanks are due to the Worshipful Company of Grocers for their generosity in providing the means of carrying out these investigations; to Professor Tommasi Crudeli for permission to use the laboratory of the Istituto d'Igiene in Rome for microscopical researches into the organisms present in the soil of Campagna which, though diligently prosecuted for some time, unfortunately led to no definite results; to Drs. Celli and Marchiafava for much kindness and facilities for study in the hospital of Santo Spirito; to the Rev. the Abbot of San Paolo fuori le Mura and the Rev. the Abbot of Tre Fontane for great personal kindness and the facilities readily granted for the prosecution of meteorological researches which would otherwise have been impossible; to the late Dr. Pantaleoni for active assistance in obtaining parlia-

mentary and other papers relating to Malaria in Italy, and for much kindly advice as to the conduct of this inquiry. Lastly the author would record his gratitude to a large number of landowners, farmers and others, and many personal friends whose uniform kindness and courtesy have done much to lighten an otherwise exceedingly laborious task.

The references to the writings of others are very numerous, and it is possible that some sources of information may have escaped recognition in the text. The author trusts that the list of works consulted given at the end of the book may compensate for any shortcomings in this respect.

WILLESDEN GREEN, N.W.
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CONTENTS

CHAPTER I.

CHAPTER II.

CHAPTER III.

CHAPTER IV.

CHAPTER V.

CHAPTER VI.

CHAPTER VII.

CHAPTER VIII.

CHAPTER IX.

CHAPTER X.

CHAPTER XI.

CHAPTER XII.

CHAPTER XIII.

CHAPTER XIV.

CHAPTER XV.

CHAPTER XVI.

CHAPTER XVII.

CHAPTER XVIII.

CHAPTER XIX.

CHAPTER XX.

CHAPTER XXI.

CHAPTER XXII.

CHAPTER XXIII.

CHAPTER XXIV.

CHAPTER XXV.

CHAPTER XXVI.

CHAPTER XXVII.

CHAPTER XXVIII.

LIST OF PLATES

ROMAN FEVER.

CHAPTER I.

INTRODUCTION.

THE group of maladies which, by a sort of general consent, have been called malarial, are perhaps the most widely distributed and the most disastrous in their effects of all the diseases to which man is liable.

Their presence renders large portions of the earth's surface absolutely uninhabitable: over still larger areas they constitute an almost insuperable obstacle to all material progress, —inasmuch as the inhabitants of those countries in which malarial disease prevails to any serious extent, labour under difficulties and disadvantages which have exerted, and always will exert, a profound influence upon the character of the race and its position in the human family.

Malarial fevers, as a rule, only become of grave consequence in tropical or sub-tropical countries. There, where nature is kind, the soil fruitful, and the climate such that for mere subsistence only a minimum of toil is required—as if by way of compensation for the harder conditions to which the dwellers in higher latitudes have to submit—the very sun which warms the soil and causes it to produce abundantly, favours in precisely the same proportion the production of a disease which is unceasingly at work, sapping the health and energies of the inhabitants, if it does not now and again take the form of a pestilence and decimate them.

To us as a nation malarial fevers are of the greatest interest and importance, though the extent to which we suffer by them is perhaps not generally realized.

The percentage of men on the sick list from these fevers during any campaign in the tropics, in which European troops are engaged, is so great, as to have justly earned for these campaigns the title of "doctors' wars." The diminution of the effective force from this cause is often greater than from all other causes combined, the words "died of fever" appearing in the death-roll far oftener than "killed in action."[1]

And it is not only in war, but also in peace, that the effects of malaria make themselves felt. Thus, taking India as an example, *one half* of the military forces of the Crown serving in that country are annually temporarily disabled from duty by malarial fevers, and the civil servants of the Government suffer in a not much less degree.

When we remember that the health of these two classes is to some extent guaranteed by their position, we shall have some notion of how great must be the disease and suffering among the native population; for we may fairly assume it to be at least as great—if not greater.[2]

Nor is it the individual alone that suffers. We must remember that sickness, and consequent incapacity for duty on the part of servants of the State, causes a serious increase in the cost of administration, which practically means increased taxation; this, for a like reason, such a country is the less able to bear, because the effect of the disease on the people is to unfit them for labour, to cause loss of time, loss of money, and generally to diminish their producing

1 During the Ashantee campaign the number of admissions per 1,000 of strength to hospital in the Rifle Brigade was—

From *all* causes	770
From fever	574

Parkes, *On the Issue of a Spirit Ration in the Ashantee Campaign*, p. 30. Churchill. 1875.

2 The total deaths registered in India in the year 1885 amounted to 5,177,600, with very imperfect registration, and of these 3,396,239 were set down to *fever alone*.

power, whilst at the same time the race, if left to itself, tends towards moral and physical degradation. Thus, other things being equal, a malarious country cannot hope for the same rate of progress as one which has not to pay this heavy tax upon its energies.

We in the present day are apt to forget, that what is now a heavy burden on other countries was once of serious consequence in our own; indeed there are districts in England, much greater in extent than is generally supposed, in which these diseases may still be said to exist, though happily in a very mild form.[1]

If, however, we go back in our history about two centuries, we find, that, in the metropolis itself, malarial fevers formed a very large percentage of the disease; and there is evidence from books of the period and the old "Bills of Mortality" that they were of a severe and sometimes fatal type.[2]

Enough has been said even thus far to show that malarial fevers are from every point of view of very great interest and importance to Englishmen, and indeed to the whole civilized world. And yet, despite the very wide distribution of these disorders, and the enormous losses of every kind which they occasion both to states and to individuals, until very lately little has been done with a view to the discovery of their cause, or the precise determination of the conditions under which they prevail; so that, if possible, by modifying or destroying these conditions, the disease may be either mitigated or driven out entirely, and the sanitary state of an infected area correspondingly improved.

As might be expected the literature of the subject is enormous and very diffuse.[3] Three-fourths of it consists of

[1] An account of the distribution of malarial disease in England, with some information regarding its gradual decline, will be found in the "Sixth Report of the Medical Officer to the Privy Council," p. 430, 1863.

[2] Compare the works of Sydenham, published by the Sydenham Society, 1848. Also *A Collection of the Yearly Tables of Mortality from* 1657 *to* 1758 *inclusive, together with several other Bills of earlier date.* London: Printed for A. Millar in the Strand, 1759.

[3] A very complete list of the more important works on the subject will be found in Hirsch's *Handbuch der Historisch Geographischen Pathologie.* Second edition, Stuttgart, 1881; and in Ziemssen's *Cyclopædia of Medicine.*

clinical observations, or "accounts" of the disease in particular places; more than three-fourths of the rest is little else than speculation, and the small residue amply represents the honest attempts which have been made to account for its origin.

Modern methods of research have somewhat increased our knowledge of the pathological changes which accompany the various forms of the disease, and a beginning has been made towards understanding the conditions essential for their production. Many apparently contradictory statements of the older writers are found to be not irreconcilable, and the germs at least of an explanation exist for the many examples of the occurrence of the disease throughout the world, under conditions apparently absolutely dissimilar: but withal we must confess that our information is exceedingly limited.

The progress of our knowledge of the ætiology and pathology of malarial fevers affords a notable example of how the very general acceptance of a plausible theory as to the nature and origin of any disease may operate seriously against its thorough investigation. Theories of some kind we must always have, they are in fact necessary, and, rightly used, serve to mark the various steps in our progress to better knowledge, and as starting points for new lines of research. Unfortunately, but too often the investigator is tempted to seek for facts to confirm the theory he has espoused, and either fails to see, or ignores, facts of equal importance which militate against it, with the result that his work has to be classified as belonging to this or that school and weighed in the balance accordingly.

Such, to a large extent, has been the character of investigations into the causes of malarial fevers. They are perhaps the oldest diseases of any great importance known to medicine, or at any rate are among the oldest; that is to say, whatever doubts there may be as to the knowledge possessed by the ancients of this or that disease of modern times, there is no room for doubt that they knew and recognised the distinctive characters of malarial fevers as such; and, more than this, in the very dawn of medical science

formed theories as to their origin and causation which remain practically unaltered to the present day. From time immemorial these fevers have been associated with marshes, as the various names by which they have been and still are known testify, and, rightly or wrongly, have almost always been attributed to exhalations or emanations from them; these, from Varro's "*Crescunt animalia quaedam minuta*" * to the *Bacillus Malariæ* of Klebs and Tommasi Crudeli, or the still more recent *Plasmodium Malariæ* of Celli and Marchiafava, have always, or almost always, taken the form of minute living organisms. In fact, we have, as far at all events as these disorders are concerned, a history of a belief in the germ theory of disease extending over at least 2,000 years—a belief that organisms arising from so-called malarious soils enter the human body and so react upon it as to produce the well-known symptoms of malarial disease.

But, whilst this theory has found perhaps more general acceptance than any other, others have been put forward. It will be our duty later to describe and classify these; to examine them carefully with a view to discovering what, if anything, they have in common, and to extract from them if possible some general principle. This we shall test, by a consideration of the distribution of malarial disease throughout the world; by a closer survey of its distribution in Europe, and more especially in Italy; and, finally, by a minute and detailed examination of the conditions under which the disease exists in the province of Rome, and of the most recent Italian researches on the subject, we will attempt to realize thoroughly the present position of the problem—What is malaria? and what is its cause?

It would be difficult to find a question on which more could be written than the one before us. Treated from the broad point of view from which we must endeavour to regard it, it involves the consideration of a number of complicated collateral subjects on which true sanitary science in its broadest sense is built, and without which we shall find ourselves utterly unable to comprehend the various conditions associ-

* *De Rê Rustica*, lib. i., cap. 12.

ated with the prevalence of the disease, or the remedial measures which have been or might be tried with advantage. The author hopes to be able to show that, despite all difficulties, there is much that might be done to rid what should be fertile and prosperous districts of this scourge of mankind, and to protect the individual against what is perhaps the most incapacitating disease to which man is liable.

CHAPTER II.

GENERAL DISTRIBUTION OF THE DISEASE THROUGHOUT THE WORLD, AND MORE ESPECIALLY IN EUROPE, WITH THE INFERENCES TO BE DRAWN FROM IT.

IT has just been stated that malarial fevers are perhaps the most widely distributed of all diseases, and that only a comparatively small portion of the earth's surface is entirely free from them. Any detailed account of their distribution would be out of place here, and has been rendered unnecessary by the lengthy and careful description given by Hirsch in his great book on Historical and Geographical Pathology, before referred to. From such an account it is however a little difficult to grasp the whole of the facts at once. We will therefore classify and arrange them in the form of a table of the various countries of the world, in the order of the intensity with which the disease prevails in them, and the better to enable the reader to realize its significance we will present it in the form of a map (Plate I.).

For the purposes of classification we must take into consideration, for any specified area, not only the *quantity* but the *quality* of the disease—that is to say, not only the number of cases, but the relative proportion of deaths; for malarial fevers do not, like some epidemic disorders—for example, cholera—kill a fairly constant proportion of their victims in all cases; but, on the contrary, the gravity of the disease is profoundly influenced by local circumstances, and it is possible in different latitudes to have an equal number of cases in proportion to population, with a mortality ranging

from practically nothing to the very high percentage attained by some epidemic disorders.

Thus it becomes clear that in any classification of the countries in which malarial fevers prevail, account must be taken, not only of their quantity as measured by number of cases, but of their intensity as measured by the percentage of deaths.

Inasmuch as the inquiry practically relates to the whole world, and more especially to the wildest and least-explored parts of it, it will be obvious that the proposed classification will depend almost entirely on the accepted reputation of the various countries, and that statistics are practically altogether wanting; still, a tabular statement, based on the general experience of persons who have visited or resided in the various parts of the globe, will serve to impress upon our minds the fact that these diseases seriously affect almost the whole human race.

For our purpose the countries of the world may be conveniently classified in four categories, according to the degree of intensity with which malarial fevers prevail in them—the fourth category comprising those in which at present these disorders do not exist.*

FIRST CATEGORY.

Countries in which malaria reaches the highest degree of intensity.

In the First Class—

Senegal, the Coasts of the Gulf of Guinea, the West Coast of Africa as far as the twentieth parallel of south latitude, Madagascar, and the Guianas.

In the Second Class—

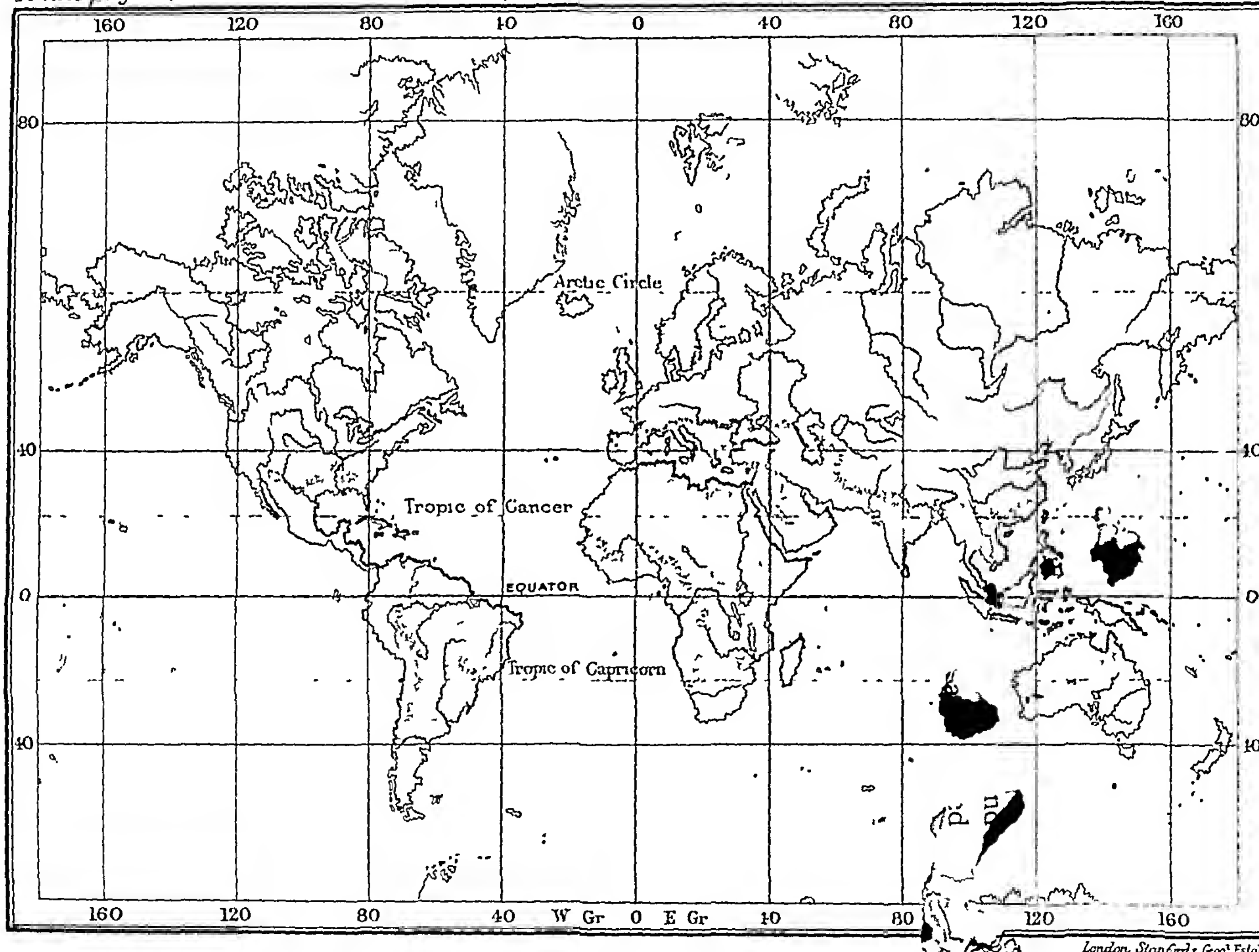
India, Cochin China, Ceylon, Afghanistan, Burma, Siam, the whole of the Malay and Philippine Archipelago, New Guinea, Nubia, parts of Abyssinia and the Soudan, and Central America.

* I am largely indebted to the work of Professor Léon Poincaré, *Prophylaxie et Géographie Médicale*, Paris, Masson, 1884, for the arrangement adopted in the above table, which substantially agrees with the facts as given by Hirsch.

To face page 8.

MAP OF THE WORLD, SHEWING DISTRIBUTION OF MALARIA.

Plate I



London: Stanford's Geog^l Estab^t

In the Third Class—

The East Coast of Africa, Egypt, the coast line of Arabia, Mexico, China Proper, the Brazils, and Peru.

SECOND CATEGORY.

In the First Class—

Tripoli, Algeria, Marocco, the [illegible]s, and the oases of the Sahara.

In the Second Class—

Turkey in Europe, Greece, the islan[illegible] Sardinia, Malta, Sicily, and parts of Ital[illegible]

In the Third Class—

Roumania, Hungary, Italy, Corsica, Spain and Portugal, Southern Russia, and large parts of the United States of America.

THIRD CATEGORY.

Southern Sweden, Denmark, Belgium and Holland, Germany, France, La Plata, Chili, and the islands of Madeira, Bourbon, Mauritius, and S. Helena.

FOURTH CATEGORY.

Countries in which malaria is altogether absent, or exists over such small areas and in so mild a form as to be of no consequence to the inhabitants.

The British Islands, Norway, the northern parts of Sweden, Finland and Russia, all North America above the fiftieth parallel of north latitude, Uruguay, the Argentine Republic, and Patagonia.

In Asia—Northern China, almost all Siberia, and the greater part of Japan,—many islands in the Pacific, New Zealand, and the southern parts of Australia.

This table requires but little comment. If we except from the Fourth Category the enormous area of thinly populated country in North America, Siberia, and Australia, the residue will be found to be but a very small fraction of the habitable globe.

Turning now to the map on which these facts are graphically represented, let us examine whether there is anything in the general distribution of the disease which will help us to any conclusion as to the conditions under which it prevails.

An atte[illegible] made, as far as is possible on so smal[illegible] a s[illegible] [illegible] four categories into which [illegible]e [illegible] [illegible]ies of the world, bearing in mind [illegible] mean relative risk to life, for, [illegible] there are many malarious districts [illegible] [illegible] escape the disease but few die from it, [illegible] [illegible] others the mortality is at times so great as almost to decimate the population, and very frequently compel its migration to some less unhealthy locality.

The first fact that strikes one on studying the map is the obvious graduation of the disease from the tropics, where it is most intense, to the poles, where it does not exist.

We must not assume from this that *all* countries in higher latitudes are less affected than *all* countries in lower latitudes, because, as we shall see later, there are conditions, irrespective of latitude, which have a very powerful influence on the existence or intensity of the disease, still, speaking generally, we are justified in saying that malarial disease diminishes from the tropics to the poles.

This establishes an obvious connection between the disease and temperature, and it is a curious fact that in the Northern Hemisphere it practically does not exist north of the annual isothermal of 4·4 C° (40 F°). In the Southern Hemisphere it is on the whole less prevalent than in the northern, and the same isothermal cuts South America at about its lowest limit; but the disproportionate amount of water in this hemisphere in a great measure destroys the comparison.

There is therefore a strong presumption that temperature is an important factor in the causation of these diseases. Does our map point to anything else?

Considering only the countries in the First Category, they are precisely those in which virgin forests and swamps flourish under a tropical sun; and though the swamps and forests

diminish in size and importance as we get north of the Tropic of Cancer, and the heat diminishes in like manner, malarial fevers still follow the water, and we find the deltas of rivers, plains, valleys liable to flood, and low-lying lands in general are the haunts of the disease, and we [illegible]annot but argue a connection between the distribution o[illegible] land and that of malarial fevers. [illegible]

Another fact, which, if we[illegible] country in the world, with the [illegible] Goths, Lombards, upon it, would come out strongly, [illegible] ravaged and history of the disease in each were acce[illegible] and burned of malarial disease to population. A dense [illegible] its former [illegible] malarial fevers are incompatible, and further, virgin soils, or soils which have been for ages neglected, are more liable to be malarious than those which have for centuries been highly cultivated.

The presence of man in sufficient numbers and the works he brings with him—provided the courage, and the numbers required to survive the earlier part of the struggle be maintained—seem to be followed to a certainty by the diminution, and possibly even by the ultimate disappearance, of malaria. This is a subject however to which we shall return in discussing the history of the disease in the province of Rome.

The malaria chart of the world appears then to justify the inference that malarious soils, in some degree, owe their quality to the combined action of heat and moisture. Let us now examine the distribution of the disease in Europe.

DISTRIBUTION IN EUROPE.

The information on which the malaria chart of the world is based is of necessity of very unequal value. Our knowledge of the existence of the disease over enormous areas in Asia, Africa, and America, is very largely dependent upon the reports of individuals; and of more than one half of it, it is at present impossible to obtain any accurate and

detailed account, so that inferences drawn from it can only be accepted in a very broad and general sense.

With regard to Europe however the case is entirely different. There are no vast unexplored tracts, and the uninhabited or sparsely inhabited districts can be measured by ordinary standards in[illegible] degrees of longitude; further, the smal[illegible] a s[illegible] it has been more or less [illegible]ies of hardly a spot on the whole [illegible]rmation is not obtainable. [illegible]tailed account of the distribution [illegible] Europe will be eminently useful, as [illegible] to test more carefully the inferences drawn from the world chart.

We have found good reason for believing that the distribution of water is, under certain circumstances, intimately connected with the distribution of the disease, and as water is largely dependent upon the physical characteristics of the country for its distribution, a study of these physical characteristics becomes of importance to our subject. More especially are we concerned with the altitude of the land.

On the annexed physical map of Europe (Plate II.) the green tint indicates land of not more than 182 metres (600 feet) above sea-level. The areas thus comprised may be briefly indicated as follows:

Beginning from the east, south of the 60th parallel of north latitude, we have an enormous area of low-lying plain which commences on the shores of the Caspian and extends thence northwards along the valleys of the rivers Ural and Volga. Barely separated from this plain are the valleys of the Don and Dnieper, the southern parts of which spread out and form the northern shores of the Black Sea, whilst to the westward these plains extend very definitely in two directions, a northern and a southern.

The northern division passes out of Russia to the Baltic coast, includes a large strip of northern Germany, and joins the lowlands of Denmark, Belgium, and Holland.

The southern division skirts the north-western shores of the Black Sea and following the line of the Danube to the

notable exceptions, entirely wanting; and our knowledge of the subject m[illegible] drawn from general historical records and the writi[illegible]ets, statesmen, and philosophers.

Such inform[illegible] can be derived from these sources is very largely [illegible]e in character, though there is enough of posi[illegible]e to the disease and the reputation of a [illegible] enable us to speak with considerable [illegible] distribution and intensity of the malaria [illegible] of Roman history.

[illegible]ising that, in the absence of direct medical [illegible]idence should be of this character; for [illegible]t pestilences, such as the Black Death an[illegible]ickness, is not an epoch-making disease. It does [illegible]pe at all events, rise to the rank of a pestilence, ca[illegible]g off its thousands and tens of thousands in a few weeks, depopulating cities and upsetting the machinery of governments; but rather in the form of an ever-present endemic, it slowly saps the energy and vitality of the people, until at last there are none left to continue the struggle, and the country is abandoned and desolate. The whole process goes on so slowly, that perhaps for several generations it may not attract attention, and affords a remarkable instance of a universal fact, known to every one at a particular period, remaining unrecorded by contemporary historians, attention only being drawn to it by later writers, who have recorded the fact that certain places in their time were fever-stricken and desolate, which, from other sources, we know once to have been flourishing and opulent.

It behoves us, then, if we would understand the origin of the present state of the Roman Campagna, to examine Roman history with a view to the discovery of such information as will enable us to form an opinion as to the state of the country at any particular epoch. To do this fully and completely would itself be a very serious task. The amount of material at our disposal for the purpose, though very scanty considering the period it covers, is far greater than might be supposed, and we must content ourselves with an examination of some of the more important links in the

chain of evidence—sufficient to give us some connected idea of the story of malaria in the province, and of the facts on which it is based.

The people who more than twenty-six centuries ago established themselves upon the Palatine cl[illegible] and laid the foundation of an empire which was ultima[illegible] ude the whole civilized world, were *not* the pionee[illegible] fort ble, a e countr[illegible] a land till then unknown, but were surrou[illegible] Goths, Lombards, and powerful communities, settled in to[illegible] 6, ravaged and cultivating the soil, and possessed of nu[illegible] ciden and burned herds. [illegible] t vast d to by its former

To the northward of the new colony l[illegible] have [illegible] om of Etruria, of whose history we know bu[illegible] destr[illegible] the Etruscans were a great people, in a high[illegible] of civilization, as the remains which still exist amply testify; and it is inconceivable that a civilized and powerful people, such as the ancient Etruscans undoubtedly were, should have established themselves and built great cities in a country so fever-stricken as the northern parts of the province of Rome and the Tuscan Maremma now are.

The same may be said, though perhaps in a less degree, of the inhabitants of the southern parts of the province. In a word, it is quite inconceivable that, at the time when these people flourished, the country they inhabited should have been as unhealthy as it is at the present day. Fever there may have been, and, possibly, in some parts of the country, of a grave type; it is even possible that, before these peoples and cities arose, it was widespread; but of this we have no knowledge. What we do know is, that their prosperity and civilization were quite incompatible with the presence among them, in any grave form, of such an enemy to progress and prosperity as malaria.

The origin of the present state of the Roman Campagna may be traced to the quasi-mythical period of Roman history. Fortunately for us, the doubtful details are of no importance to our subject. It is sufficient for us to know that a colony of strangers planted themselves upon the Palatine Hill, and, by virtue of their superior skill and energy in the arts of war,

continued to subdue and conquer the various peoples whose towns and villages covered the country in their immediate neighbourhood. We know from the writings of Livy how numerous these peoples were; and can form some opinion of their prosper[illegible] importance from the account he gives of the mil[illegible]hey could put into the field; and, making [illegible]xaggeration, there can be no reasonable [illegible] were numerous, possessed of considerable [illegible]ape of flocks and herds, and, as far as we [illegible] upon the rearing of cattle and the tillage [illegible] continued existence.

[illegible]een these peoples and the new-comers last[illegible]an four hundred years, and, from such accounts a[illegible] it is probable that during this period the intervals of peace were [illegible] few and far between; and not only was the country torn by internal strife, but Rome was three times called upon to defend herself against the Gauls, who, on one occasion at least, sacked and burned the city, and reduced the Romans to the direst straits.

This long period of turmoil must have had a disastrous effect upon the prosperity of the country, by interfering with the agricultural pursuits of the population; and it is not surprising that we find frequent records of famine and pestilence.[1] But this is not all, the Romans, driven to desperation by the perpetual forays of their neighbours, seem to have acted upon the advice of Furius Camillus—to devastate all Latium, and make of it a vast solitude.[2] This much is certain, that after the date fixed by Livy, at which this advice was given, numbers of the towns of Latium disappear from Roman history, and Pliny the Elder, writing four centuries later, speaks of *fifty-three* peoples who had disappeared from ancient Latium and left no trace behind.[3]

Interesting and important to our subject though it be, it hardly falls within the scope of this work to trace the relation of the people to the soil, throughout the history of the Roman republic. But the general results of the policy of Rome

[1] Livy, iii. 13; v. 13; vi. 21. [2] Livy, viii. 13.
[3] Pliny, *Nat. Hist.* iii. 5.

during this period, and the changes brought about by her wars with Carthage, cannot be overlooked.

As we have seen, the treatment of the cities of Latium was severe. Many were destroyed, their inhabitants transported to Rome, and their lands divided among her citizens. To others military colonies were sent, which involved a corresponding loss of territory. The city inc[illegible] size and population, and the plebeians, once so ten[illegible] [illegible]ht to a share in the public lands, began to pre[illegible] to be content to sell or barter away their [illegible] proprietors; and thus was formed the nucl[illegible] mob, who cared for nothing so long as the[illegible] bread and their shows in the circus, a[illegible] sell themselves to the highest bidder, their [illegible]ence made them in a sense masters of the sit[illegible] The Roman citizen (*sic*) despised the arts of agriculture.[1] Successful foreign wars had filled the coffers of the state with gold, and the land with slaves. The small yeoman disappeared, and the country was divided and redivided among the followers and partizans of one successful general after another; and Rome increased at the expense of the surrounding cities, which, one by one, vanished into oblivion.

Pliny the Elder[2] declares that the large estates (*latifundia*) were the ruin of Italy and the provinces; but besides the causes of their existence already enumerated, there was another, which served at the same time to complete the destruction of agriculture in Central Italy, and which operates powerfully to this day, not only in Italy but in England.

The Punic wars opened Africa to Roman trade, with the result that Africa became the granary of Rome, and the growing of corn in Italy was no longer profitable.[3]

The supply was practically unlimited, and cheap, and wealthy generals and statesmen were not slow to avail

[1] Columella, *De Rê Rusticâ*, lib. i. 4.

[2] "Verumque confitentibus latifundia perdidere Italiam: jam vero et provincias."—*Nat. Hist.* xviii. 6.

[3] "Vita populi Romani per incerta maris et tempestatium quotidie volvitur"—TACITUS, *Annals*, iii. 54.

themselves of the opportunity thus afforded of purchasing the goodwill of the Roman populace.

The land in Italy, and especially in the province of Rome, which once fed its own population, was deserted by the husbandman,[1] to be covered by the villas and gardens of the wealthy ; and th[illegible]llage and cultivation, though undoubtedly of a very [illegible], was unprofitable, and entirely performed by [illegible]

[illegible] labour played a most important part in the [illegible] general cultivation as was still practised. [illegible]ak after another taught the Romans the deper[illegible] they had created. The remedy adopted was [illegible] the people and the times. The risings were [illegible]ied, and the land laid down in pasture, because the [illegible] number of slaves employed could be materially reduced ; and whilst the danger of fresh risings was diminished, the profit of the owner was probably increased, and in this way, vast tracts of thinly populated pasture land arose in Central Italy.

As the wealth and splendour of Rome increased, the whole province, and more especially the coast line, became studded with the villas and country houses of her emperors, statesmen, and successful soldiers,[3] filled with everything that the wealth and luxury of the times could suggest, as the ruins with which the country is strewn to this day testify.[4]

The civil wars of the later days of the republic, and the rivalries of the Cæsars, do not appear to have interfered with the progress of this luxury and extravagance, and the Romans appear to have continued this mode of life, more or less in peace, during the first three centuries of the Christian era—in fact, until Constantine removed the seat of empire to Byzantium.

How disastrous to Italy was this removal is a matter of

[1] Lucan, *Pharsalia*, vii. 391 ; Horace, *Odes*, ii. 15.

[2] Pliny, *Nat. Hist.* xxxiii. 10.

[3] Pliny, *Epist.* ii. 17 ; Tacitus, *Annals*, iii. 54 (Walther) ; Frontinus, *De Aquæductibus Urbis Romæ*, cap. 9.

[4] Valerius Maximus, ix. 1 ; Pliny, *Epist.* ii. 17 ; Velleius Paterculus, ii. 1 ; Horace, *Odes*, ii. 15.

history. Rome sank to the level of a provincial city, and her wealth and learning followed the government to the new capital. Nor was this all. The official recognition of the Christian religion, by Constantine in the edict of Milan,[1] and subsequent legislation, deprived the owners of the soil of all slaves who embraced Christianity,[2] the practical outcome of which was, that the land went out of cultivation.

But a worse fate was in store for the unfortunate country, in the shape of invasion by the Vandals, Goths, Lombards, and Saracens, who, from A.D. 408 to A.D. 846, ravaged and plundered the Roman province—ten times sacked and burned the imperial city, and left it a mere shadow of its former *magnificence.*[3]

Procopius, the secretary of Belisarius, tells of the destruction of the aqueducts, and how the huge armies of Vitiges and Totila harried the country round Rome;[4] and the latter, in his rage at the stout resistance made by Tibur (Tivoli) to his arms, is said to have destroyed the great villa of the Emperor Hadrian below the town.[5]

The damage done by the Goths and Vandals seems, however, to have been as nothing compared with the work of the Lombards, to whom must be attributed the ruin and desolation of the Campagna, from which to this day it has never recovered, and which Gregory the Great described in the words, "Depopulati sunt agri—nullus in agris incola."

Hardly had the Lombards settled down, and some traces of order been restored, when the Saracens descended upon the shores of the province, and plundered and burnt at will. All order and government disappeared, and the country was left *to the tender mercies of rival popes and barons, who, when* occasion seemed to require it, invited to their aid others worse than themselves; one of whom, Robert Guiscard (A.D. 1081), earned for himself and his followers a reputation even worse than that of Astolfo, king of the Lombards (A.D. 752).

[1] Eusebius, *Hist. Eccl.* x. 5.

[2] *Codex Theodos*, tit. vii. "De Manumissionibus in Ecclesia;" *Codex Justinianus*, i. 10.

[3] Gibbon, *Decline and Fall*, cap. xlv.

[4] Procopius, *De Bello Vandalico*, and *De Bello Gothico*.

[5] Nibby, *Dintorni di Roma*, iii. 653.

All through the middle ages this state of chaos and misery continued. The Campagna was the battle-ground of barons, freebooters, and pirates (Barbarossa), who ravaged the coast and penetrated far inland. The insecurity of life and property was such, that agriculture was utterly neglected, and the population reduced to insignificance.*

The results of the labour of centuries were completely lost, and the land returned to something worse than its original natural state; whilst the Eternal City itself, after it had been sacked and burnt by the Connétable de Bourbon (1527), reached a degree of squalor and misery from which recovery seemed impossible. From that d[illegible]ne and neglect have continued the work of degradation, [illegible] is only within comparatively recent times that the process of restoration has begun.

Such, in brief, is the history of the Roman Campagna, and of the causes which have led to its present desolate and neglected condition.

Comment is unnecessary. The abandonment of the soil by its inhabitants, when subjected for centuries to such vicissitudes of fortune as above detailed, is only what might reasonably be expected to occur, and we might consider ourselves justified in assuming, that the malaria can have played but a very small part in promoting this abandonment. Assuming this to be the case, we must now trace the history of the disease in the province of Rome, in order to discover how far it is the effect of the neglect and desertion of the soil, or whether it is a mere concomitant—a something which has arisen and increased *pari passu* with the increasing misery of the country.

We must, as we have already said, derive a large portion of our history of malarial fevers in the province of Rome from the classic writers and their successors. This part of our inquiry divides itself at once into: (*a*) direct references to the disease, and, (*b*) references to localities in which it prevailed.

If we except the works of Celsus and Galen, our information as to the knowledge possessed by the ancient Romans of malarial fevers is entirely derived from non-medical sources.

* Rome, in 1377, is said to have had only 17,000 inhabitants.

References of this kind have, to some extent, an even greater value than isolated professional treatises on the nature and treatment of the disease, for, in the absence of any definite account of its distribution and intensity, they afford a means of estimating how far the general public was familiar with it, and the circumstances under which it might be acquired. No apology is, therefore, necessary for presenting to the reader the whole of the evidence which is obtainable, and leaving him to form an opinion as to its significance.

The references are for the most part accidental; and of a large number it may be said, that there is at least considerable doubt as to the precise disease referred to by the author. Some recent writers on the subject would have us believe that many of the great pestilences of which we have record were malarial. There is, however, but slight justification for this view. For the most part, they followed upon war and times of scarcity; the mortality, as a rule, was great, and the disease communicable from one individual to another; more than this, it is recorded in many cases that the cattle suffered as much as human beings, if not more. Altogether, in the absence of all proof to the contrary, it would seem more just to assume, that these visitations were not malarial, but rather of the nature of malignant typhus, or plague, so-called. At any rate, there is no proof whatsoever that they *were* malarial, and not only so, but it is highly improbable that such was the case; for, as far as our experience goes, epidemic malaria of a grave type is chiefly confined to the tropics, and even there is not common. We may, therefore, dismiss all accounts of malignant epidemics as beyond the scope of our inquiry, and turn to such direct and positive evidence of the existence of true intermittent fever in the province of Rome as can be found in the writers of antiquity. The evidence, as we have just said, is of two kinds—direct mention or description of the disease, or intimation of the unhealthiness of certain localities. This latter group of evidence is perhaps not so satisfactory as the former, but, inasmuch as malaria is essentially a disease affecting a definite locality—and it has already been shown that certain qualities and properties

attach to malarious districts—we may possibly be justified in assuming, broadly, that when a given locality is spoken of as being unhealthy, and further, as having the above characteristics, the unhealthiness consists in the prevalence of malarial fevers.

We will take the evidence under both heads in chronological order, and endeavour to trace, at the same time, the spread of the disease and the causes which have led to it. For, as will be seen, it is impossible to separate them.

Cato the Censor (B.C. 232—148).—The advice given by this author[1] as to the choice of a site for a country house has been supposed by some writers to imply an acquaintance with malaria and malarious localities, but a little consideration makes this appear a very strained interpretation of a passage intended to be of the most general application. Further, Cato was a keen observer, and wrote a treatise on medicine[2] and malaria, being, as it is, essentially a property of the locality, it is hardly conceivable that he should have omitted specific mention of it, had he been acquainted with the disease. We are, therefore, plainly justified in assuming that in Cato's time malarial disease either did not prevail at all in the Roman province, or was so insignificant as to attract no attention whatever.

Varro, Marcus Terentius (B.C. 118—29) writes—"Advertendum etiam signa erunt loca palustria et propter easdem causas, et quod arescunt, CRESCUNT ANIMALIA QUAEDAM MINUTA, QUÆ NON POSSUNT OCULI CONSEQUI, et per æra intus in corpus per os, ac nares perveniunt, atque efficiunt difficiles morbos."[3]

This passage leaves no room for doubt, that in the author's time, the unhealthiness of marshy places was well recognized; though whether the "*difficiles morbos*" signify malarial disease or no, is by no means clear; nor in the whole of the rest of his treatise is there any further reference to them. The passage is however, of peculiar interest, as containing a

[1] *De Rê Rusticâ*, lib. i. [2] Pliny, *Nat. Hist.* xxv. 2, and xxix. 1.
[3] *De Rê Rusticâ*, lib. i. cap. 12.

statement of a theory as to the origin of disease which is popular in the present day, and which, though based on mere conjecture, would serve perfectly as a definition of at least one modern theory as to the causation of malarial fevers.

Cicero (B.C. 106-43).—Cicero's letters to his freedman Tiro are full of urgent inquiries as to his health; and it appears from one of them[1] that his disease was ague, and had assumed the quartan type, for which reason Cicero congratulates his friend as being in a fair way to recover entirely. Again[2] he clearly distinguishes between tertian and quartan fever, and attributes their regular periodicity to the will of the gods.

There is, therefore, no doubt whatever that in Cicero's time the forms of intermittent fever were well known, and though it is quite possible that in the case referred to the disease was acquired on foreign service, the reference cannot but excite suspicion that these fevers were known in the province of Rome; although in the writings of Cicero it is nowhere specifically stated that such was the case.

Lucretius (B.C. 98-55).—It is somewhat curious to find Cicero speculating on the causes of periodicity and Lucretius silent. His book *De Rerum Natura*, contains no mention of ague as such, though most of his references[3] to fever might be construed into a reference to the disease. It is impossible to suppose that Lucretius was less acquainted with intermittent fever than Cicero; and we can only conclude, that though known to the Romans either at home or abroad, or both, it was not of sufficient gravity to be of material consequence.

Virgil (B.C. 70-19) and Ovid (B.C. 43-A.D. 17) make no mention of ague in any of their writings. Horace[4] refers to it by name only once, but in such terms as to make it clear that he was no stranger to the phenomena of the disease.

[1] *Epist.* xi. lib. xvi. (ed. Ernesti). [2] *De Natura Deorum*, iii. 10.

[3] Lucretius, *De Rerum Natura*, lib. ii. 34, vi. 656, vi. 804.

[4] "Jupiter ingentes qui das adimisque dolores,
Mater ait pueri menses jam quinque cubantis
Frigida si puerum quartana reliquerit, illo
Mane die, quo tu indicis jejunia, nudus
In Tiberi stabit."—*Satires*, lib. ii. iii. 291.

Pliny the Elder (A.D. 23-A.D. 79), in his *Natural History*, makes frequent reference by name to tertian and quartan ague; describes the symptoms more or less vaguely, and gives a number of charms against it and remedies of various kinds, showing that he was well acquainted with the disease in its different forms; and though, unfortunately, he does not name any place or places as being malarious, the fact of the existence of charms against ague is sufficient to prove that it was well known to the people in his time.*

Suetonius, who flourished under Trajan, in his life of Julius Cæsar, says that Cæsar in his flight from the emissaries of Sulla, was obliged frequently to change his hiding-place. "Quamquam morbo quartanæ aggravante."

Juvenal (A.D. 48-121), *Satire* ix. 17, has "torret quarta dies olimque *domestica* febris," which can only be taken to imply familiarity with ague on the part of the writer.

Celsus, *De Medecina*, iii.-3, recognizes and defines quotidian, tertian, and quartan ague, and in the same book discusses their treatment.

So far, then, as references in the classic authors concern us, we may take it for granted that ague was a well recognized and common malady among the Romans at the beginning of the Christian era; and, further, that whilst precise information on the subject is wanting, we have no evidence of its being recognized as a specific disease before the time of Cicero; though the references already given to the works of Cato and Varro lead us to suspect that in their time certain localities were unhealthy: and from the description of these localities it would seem probable that the cause was malaria.

The existence of the disease in classic times being thus clearly proved, we have now to consider the evidence as to the localities infected, and the gradual extension of the malaria over the whole province.

* Pliny, *Nat. Hist.* xx. 6, 3, 14, 20, xxi. 30, xxii. 14, 30, xxv. 8, xxvi. 11, xxviii. 7, 8, 16, xxx. 11, xxxii. 10.

HISTORY OF THE DESERTION OF LOCALITIES IN THE PROVINCE OF ROME, PRESUMABLY BECAUSE MALARIOUS.

In tracing the history of the desertion of specified localities, and in this or that case assigning malaria as the cause, we are treading on very difficult ground; for, from the brief sketch which has been given of the general history of the Campagna, it is clear that many causes were in operation, any one of which might have led to the abandonment of a given site by its inhabitants.

To begin with the list of "oppida præclara" given by Pliny (*loc. cit.*), we should be very far wrong in assuming that malaria was the cause of their desertion and disappearance, and perhaps equally wrong if we assumed that it was not. That in many cases malaria played its part, there can be very little doubt; and by examining the references in classic and other writers to what are now notoriously unhealthy places, we may be able to form some opinion as to how, and at what time, malaria became a serious disease in the province of Rome.

Bearing in mind the vague warnings contained in the passages which have been cited from Cato and Varro as to the unhealthiness of marshy districts, and the facts already stated regarding the nature of the soil of the Campagna, which has certainly not altered within historic times, we shall not be surprised to find that a tendency towards marsh and bog is characteristic of this soil, when left to the operations of nature, and that places so abandoned became unhealthy, or, in other words, malarious. It being clearly understood, however, that there is no necessary connection between marshes and malaria.

To cite all the instances which might be given, and relate their story in detail, would be to trench upon the domain of the historian and the antiquary, without materially forwarding the object of our inquiry. Still, we cannot be said to have in any way fulfilled our task without considering a few of the more important examples of the gradual abandonment of

localities, and the subsequent development in them of malarial disease.

The example which, historically and in every other sense, is to us the most important, is that of the Pontine region,* and to this we will now address ourselves (Plate XI.).

On the authority of Dionysius of Halicarnassus (iv. 9), Tarquinius Superbus sent colonies from Rome, A.U.C. 227, B.C. 526, "in campis pomptinis qui omnium camporum agro Latino marique contiguo finitimorum sunt maximi." A fact implying the existence of an amount of cultivable land in the district hardly compatible with large areas of marsh and flooded ground; though we have proof that an area, probably not of very large extent, to landward of the city of Anxur (now Terracina), was marshy from very early times. For Livy (iv. 59), in his account of the Volscian war, A.U.C. 349, B.C. 403, says—"Anxur fuit, quæ nunc Tarracinæ sunt: *urbs prona in paludes.*" Whilst, in recounting the events of another war against the same people, A.U.C. 370, B.C. 382 (vi. 12), he expresses surprise that peoples such as the Volsci and Equi were, could provide the soldiers necessary to maintain the armies with which they so obstinately resisted the Romans; and contrasts the state of the district in their time with his own, in which "vix seminario exiguo militum relicto, servitia Romana ab solitudine vindicant." And (iv. 21) he again describes the inhabitants of the Pontine region as keeping the Roman soldiers "eternally employed."

Despite their prolonged resistance, these brave people had to submit to absorption into the Roman state; and in the year A.U.C. 397, B.C. 355, their lands were divided and two new tribes formed, the Pontine and the Publilian (Livy, vii. 15).

Our more definite knowledge of the Pontine district begins with the construction of the Via Appia by Appius Claudius,

* Those who desire fuller and more complete information should consult—Nicola Maria Nicolai, *Dei Bonificamenti delle Terre Pontine*, libri iv.; *Roma nella Stamperia Pagliarini* MDCCC. fol.; and Tito Berti, *Le Paludi Pontine.* Roma, 1884; De Prony, *Description Hydrographique et Historique des Marais Pontins.* Paris, 1822. *Études statistique sur Rome et la Partie Occidentale des États Romains.* Par M. le Comte de Tournon. Paris, 1855.

the Censor, A.U.C. 442, B.C. 310,[1] and the history of its maintenance. There is no mention of anything which need concern us recorded until A.U.C. 594, B.C. 158, when we find recorded by Florus, in his epitome of the lost books of Livy (lib. xlvi.), the following very significant fact:—"Pomptinæ paludes a Cornelio Cethego consule . . . . siccatæ, agerque ex iis factus." The work was apparently performed in *one* year, as Cethegus was not re-elected consul. Here we have clear and distinct evidence, that, either from neglect or some other unknown cause, the drainage of the Pontine region was unsatisfactory at this time. We can gather little more from this one sentence, except that, inasmuch as the work was completed within the consulship, *i.e.* in *one* year, it could not have been very serious.

A few years later, B.C. 88—86, the cities of the Pontine region were sacked and burned, and their inhabitants slaughtered in the terrible civil war between Marius and Sulla, and during this period we have no information whatever regarding the state of the drainage; but it would appear, from Aulus Gellius, *Noctes Atticæ*, xi. 17, that the streams were kept clean and open, and that this work was regularly contracted for, so that the neglect of it might be expected to result in the flooding of the neighbouring land. This necessary duty probably was neglected during the turmoil of the civil wars, and it is not, therefore, surprising to find, when peace was restored, that the attention of Julius Cæsar was attracted to the state of the Pontine region, and that he intended to have drained it, had not death prevented the execution of his plans.[2]

According to Dio Cassius (lib. xlv.), Marc Antony endeavoured to gain popularity by the drainage and redivision of these lands, "Qui essent in paludibus Pomptinis VELUTI JAM COMPLANATIS ATQUE AGRICOLTURÆ APTIS."

From which passage it is plain, that shortly after the death

[1] Livy, ix. 29; Cicero, *Pro M. Cælio*, xv.; Diodorus Siculus, lib. xx. "Frontinus, *De Aquæductibus Urbis Romæ*," 5.

[2] Suetonius, in *Jul. Cæs.* cap. 44; Cicero, *Philipp.* 3; Dio Cassius; Plutarch.

of Julius Cæsar, the land in the Pontine district was to a very considerable extent *unfit* for agriculture. Let us now turn to the writers of the period for information as to its general state, and more especially its reputation for unhealthiness.

The account given by Horace (*Sat.* i. 5) of his journey by boat from Forum Appii to Terracina, at night, and of the frogs and mosquitos which together prevented him from sleeping, makes it almost certain that the land on either side of the Via Appia was, in his time, marshy in the ordinary sense of the word.

Virgil (*Æneid*, vii. 800) has—

"Qua Saturæ jacet alta palus."

Though this may refer to the ancient marsh near Terracina mentioned by Livy, *loc. cit.* (p. 78).

Ovid (*Metam.*, xv. 717)—

"Trachasque obsessa palude
Et tellus Circea, &c."

Juvenal (iii. 307)—

"Et Pomptina palus, et Gallinaria pinus."

Silius Italicus (l. viii. 381) goes a step further—

"Et quos pestifera Pomptini uligine campi
Qua Saturæ nebulosa palus restagnat, et atro
Liventes cœno per squallida turbidus arva
Cogit aquas Ufens atque inficit æquora limo."

Indicating a considerable extension of the marshy ground beyond the neighbourhood of Terracina. The river Ufens, now the Uffente, had apparently in his time (A.D. 15—90) got beyond control, and spread its waters over the country.

Lucan (*Pharsalia*, iii. 84)—

"Tamque et præcipites superaverat Anxuris arces
Et qua Pomptina via dividit uda paludes."

And Vitruvius (i. 4)—

"Quibus autem insidentes sunt paludes, et non habent publicos exitus profluentes, neque per flumina, neque per fossas, uti pomptinæ, stando putrescunt, et humores graves et *pestilentes* in iis locis emittunt."

We may close the list with the well-worn passage from Strabo (lib. v.)—

"Omne Latium felix est, et omnium rerum ferax, exceptis locis quæ PALUSTRIA SUNT ATQUE MORBOSA, qualis est Ardeatinus ager inter Antium et Lavinium usque ad Pometiam, et Setini agri quædam et circa Tarracinam et Circejum."

That is to say—"All Latium is fertile . . . . *except those places which are marshy and productive of disease*, such as the neighbourhood of Ardea, between Antium and Lavinium, as far as Pometia, and parts of the country near Sezze, and about Terracina and Circe."

Following these references in chronological order, we seem to realize that the Pontine region, from some cause unknown, but probably neglect of the drainage and care of the streams, became marshy in parts; that this marshy area steadily extended; and finally we have Strabo declaring that it is pestilent, and productive of disease. What the disease or diseases were to which Strabo refers, we do not know for certain; but they have generally, and with justice, been assumed to be ague and paludal cachexia, probably including also rheumatic affections of all kinds.

Strabo's opinion is borne out by a passage of Seneca (*Epist.* cv.), who, writing to a friend, says—

" . . . . Quæ observanda tibi sint ut tutior vivas, dicam. En tamen sic audias censeo ista præcepta, quomodo si tibi præciperem, qua ratione bonam valetudinem in Ardeatino tueris."

Which seems to indicate that the Ardeatinus ager was not as healthy as could be desired, and that certain precautions

were necessary on the part of those who lived within its borders.

Thus, in about five centuries, the Pontine district was converted from a fertile land, so thickly peopled with warlike inhabitants as to excite the wonder of the historian, into a dreary marsh, with but few inhabitants and more or less unhealthy. Yet it was very far from being as unhealthy as at the present day; and the unhealthiness, by whatsoever disease it was represented, was most certainly *not* the cause of its depopulation at this epoch. For at the very time at which some writers describe the Pontine region as "pestilens," it contained not a few of those sumptuous villas for which the Romans in the palmy days of the Empire were so famous.

Lucullus had a villa at the foot of Monte Circeo, Antony another near Sezze,[1] though Cicero says of it, that it was "neque amœnum neque salubrem locum." At a place now called Vallejavone was the villa of a wealthy freedman of the Gens Æmilia, and Augustus himself is said to have had one in this region. The Gens Julia had a country house near Bassiano; and some remains near Piperno are said to mark the site of the villa of Sejanus, the favourite of the Emperor Tiberius. So that though the immediate vicinity of the Via Appia had undoubtedly become very marshy, and perhaps unhealthy, in the early part of the first century A.D., the state of the district was not such as materially to interfere with either the health or enjoyment of the owners of the villas above mentioned. Cicero's favourite country house was on the coast,[2] some eight miles south of the modern Astura, and practically in the Pontine region.

The maintenance of the Via Appia seems to have been the motive for draining the Pontine territory, rather than any notion of thereby rendering it less unhealthy; and it is in this connection that we hear of it down to the sixth century.

Nero's mad project of driving a canal from Ostia to Baiæ, to avoid the sea journey,[3] is perhaps hardly worth mentioning;

[1] Cicero, *De Oratore*, ii. 71.

[2] *Ad Atticum*, xii. 19.

[3] Tacitus, *Annals*, xv. 42; Suetonius, *In Nerone*, 31; Pliny, *Nat. Hist.*, xiv. 6.

but Pliny in another part of the same work[1] says, "Siccentur hodie Æthiopidæ Pontinæ paludes tantumque agri suburbanæ reddatur Italiæ." An unmistakable reference to the reclamation of the flooded land.

Nerva began, and Trajan completed, a thorough restoration of the Via Appia; built bridges, and constructed various works for the control of the streams.[2] Their successors endeavoured for a time to maintain their work; and Antoninus Pius cleared and rebuilt the port of Terracina;[3] but their efforts became more and more feeble. The inroads of the northern hordes put an end to all public works whatsoever, till, under Theodoric, something like peace was restored; and by his orders the Pontine marshes were drained by Patricius Decius, and the Via Appia put into a state of thorough repair (Cassiodorus). The drainage must have been very complete and successful, for the cavalry of the army of Vitiges found pasture there a few years later.[4]

The history of the district during the succeeding centuries is one of prolonged neglect. By a rescript of Pepin, the control of it was handed over to the Popes, and it is to the Popes we now have to look for the execution of drainage works in the Pontine region. Up to about A.D. 1300 little was done beyond farming the eel fishery; but under Boniface VIII. something was attempted in the way of collecting the scattered water into definite channels. Pope Martin V., in the early part of the fifteenth century, constructed further canals, and his successors at intervals kept up the work. But it is to Sisto Quinto (1585-1589) that the honour of having thoroughly and systematically attacked the problem must be given. He went down to Terracina himself to superintend the operations, and stayed fifteen days in the neighbourhood dying ten months afterwards of a tertian ague, in Rome, leaving his great work unfinished. Pope Urban VIII. (1637) employed Dutch engineers to continue and complete the operations of Sisto Quinto; and his successors, from time

[1] Pliny, *Nat. Hist.*, xxvi. 4. [2] *Dio Cassius*, 68; Galen, *Mat. Med.*, q. 8.
[3] Julius Capitolinus, in *Ant. Pio*, cap. viii.
[4] Procopius, *De Bello Gothico*, i. 11, i. 16.

to time, executed works for the reclamation of land in the Pontine region, which had then begun to attract general attention in Europe. Clement XIII. took the matter in hand, and appointed a commission of inquiry, which reported (1759) that the banks had given way everywhere, the beds of the canals were filled up with rubbish, trunks of trees, and the like, and were in many cases blocked entirely. The works were begun, and 200,000 scudi (£40,000) were spent upon them ; but they were ultimately stopped from want of funds, and by the opposition of the local landowners, and others, who derived great profits from the fishery which the drainage works threatened with extinction.

The great works planned under the direction of Pius VI., and executed at the close of the last century, during the occupation of the country by the French, appear to have produced solid benefit. Large tracts of flooded land were reclaimed and rendered fit for cultivation ; and, by a careful supervision of the canals and drains then constructed, the advantage has been maintained. Still, the amount of water in the area is very great, and though to a large extent under control, the nature of the soil is such that it is always more or less water-logged ; whilst there is, unfortunately, no doubt that the malaria is far more intense and wide-spread in the present day than it was in the early centuries of the Christian era. The written records of its progress are very scanty, and for the most part indirect. But, on the plain below Norma, stands a sort of monument to the defeat of man in his struggle against misery and disease in the ruins of the town of Ninfa, the walls of the houses of which still remain, and the greater part of a church, but the streets are overgrown with grass, and all is silent and deserted.*

The story of Ninfa, from our point of view, is exceedingly interesting ; but we must content ourselves with reference to such facts as will show when it flourished, and when it was deserted, as affording some indication of the time at which the malaria became too intense for man to continue the struggle against it.

* Ferdinand Gregorovius, *Lateinische Sommer*, p. 191.

Ninfa was apparently a new city in the time of Pope Zacharias, A.D. 743, and, with the town of Norba and the surrounding country, was presented by the Emperor Constantine Copronymus to the Pope, in gratitude for his intervention with Luitprand, King of the Lombards, to prevent the annexation by the latter of several Italian cities—notably of Ravenna and the Exarchate,* in 1159. Pope Alexander III. was consecrated there; and through all the troubles with the barons in the thirteenth century, Ninfa remained faithful to the Popes, though it must have suffered severely in the perpetual wars which raged in the Pontine region at this epoch. The name continues to appear in Papal Bulls and Rescripts down to the sixteenth century, when, according to a tradition still existing, and which was told to the writer when he visited the place, it was sacked and burned by the Turkish corsair, Hayraddin Barbarossa, probably about 1534, and from that time it seems to have disappeared from history.

The few wretched people who live in hovels around a corn mill on the River Ninfa, close to the ruins of the town, are now typical examples of the very worst forms of malarial cachexia. The workmen at the mill go up to Norma to sleep, to avoid as much as possible the risk of fever, and the neighbourhood is to the last degree pestilent and utterly unfit for human habitation.

This cannot have been the case in 1534, when Ninfa was inhabited. We know that, at the end of the sixteenth century, under Sisto Quinto, the whole Pontine region was malarious, and that during the last three centuries the disease has increased in intensity and extended itself over larger areas, invading the lower slopes of the surrounding hills, and reducing the once flourishing towns on them, such as Sezze and Sermoneta, to a state of squalor and misery which baffles description.

Such, in very brief, is the story of the Pontine marshes. Let us now turn to some examples of the invasion by the disease of other parts of the province.

It is exceedingly probable that, apart from the towns

* Muratori, *Antiq. Ital.* tom. v. p. 838.

which Pliny says had actually disappeared in his day, there were a number of others undergoing the process of extinction, for many of the classic writers speak in terms of contempt of places which had played an important part in the early history of Rome.

To quote all the instances would be tedious and unprofitable. The "Ulubræ vacuæ" of Juvenal,[1] and the "Collatia et Antemnæ vici" of Strabo,[2] the "Gabiis desertior atque Fidenis vicus" of Horace,[3] and passages in Cicero[4] and Florus,[5] with many others which might be cited, serve to show the tendency to the desertion of the small towns of the Campagna, and the probable absorption of their population into that of the city.

But whilst this was going on, and apparently recognized by contemporary writers, the villas along the littoral increased in number and splendour; and it is utterly inconceivable that malaria could have prevailed on their sites. Pliny's villa at Laurentum was, as he tells us,[6] only one of many in the neighbourhood which could be seen from his tower. And, in *Epist.* iii. 14, he mentions Formia as the site of the villa of an acquaintance. The present name of the place is Campo Morto, or the field of death, so unhealthy is it; and yet it is praised by Martial as being far more enjoyable than Tivoli, Tusculum, Antium, and other places.[7]

Years after the death of Pliny the younger, the Emperor Commodus fled to Laurentum to avoid a pestilence then raging in Rome.[8]

The villa of the Emperor Antoninus Pius at Lorium (Castel di Guido) was deserted in the time of Diocletian (A.D. 284-305).[9] But the city, or castle, of Lorium was inhabited for a long time after, for it is mentioned in a Bull of Pope John XIX., A.D. 1024.[10]

Rocca Cenci, eight miles from Rome, on the Via Gabina, is

[1] *Sat* x. 102. [2] v. 226. [3] *Epist.* i. 11, 7.
[4] *De Lege Agraria*, ii. 35. [5] i. 11. [6] *Epist.* ii. 17.
[7] *Epigram.*, lib. x. 30. Cf. Cicero, *Ad Atticum*, i. 4, and xv. 13; also *Epist.* xvi. 10. [8] Herodian, *Hist.* lib. i.
[9] Julius Capitolinus in *Anton. Pio*, cap. i.
[10] Ughelli Italia Sacra, cited by Nicolai, *Annona di Roma*, i. 99.

believed to be the site of the ancient Papinia, of which Columella [1] says, that it was "pestilentis simul et exilis agri," but became healthy after cultivation. It has regained its previous character in the course of centuries, though when it ceased to be healthy is unknown.

The history of Galera, on the River Arrone, a few miles west of Veii, is perhaps as continuous as that of any place in the Roman Campagna. It seems originally to have been a mere station on the Via Claudia (ad Carcias).[2] The town does not appear to have been built until about the twelfth century; and there is a history of the doings of the Orsini family, as lords of Galera, up to the year 1670, when it was sold in order to raise money. On April 18th, 1536, it provided lodging for the Emperor Charles V. and his train, on his way from Rome; but, a hundred years later, in 1636, the population had sunk to 300 souls; in 1660, to 170; in 1667, to 130; in 1700 it rose to 150; but in 1809, it was deserted entirely; and is now a mass of ruins, and excessively unhealthy.[3] A proposal was made in 1830 to repeople it, but was never carried out.

The story of Galera will apply to many other places in the Campagna—once they were inhabited, now they are deserted, and if we examine their history carefully, we always, or almost always, find that their ruin began from political causes, and that the malaria seems but to finish the work so begun.

That the Roman Campagna at the end of the sixteenth century contained a large number of inhabited places, in districts now too unhealthy for habitation, at least all the year round, is certain, because Pope Sisto Quinto, finding that the population of many of them practised brigandage as a means of earning a livelihood, waged a war of extermination against them, and destroyed their strongholds.

So far the story of the decay of localities. We may fitly close this part of our subject with a very brief review of some attempts to arrest the progress of the desertion of the Campagna made in very early times.

[1] *De Re Rustica*, lib. i. cap. 4.

[2] Frontinus, *De Aquæductibus Urbis Romæ*, 71. Cf. also Westphal, *Die Römische Kampagne*, p. 153.

[3] Nibby, *Dintorni di Roma*, ii. 98.

In the eighth century, when the invasion of the northern barbarians had ceased, Pope Zacharias instituted what were called Domuscultæ (A.D. 741-752), and Adrian I. (A.D. 771-795) continued and extended them.

The first-named Pope founded three small villages—one on the Via Claudia, called Loreto; one on the Via Tiburtina, called St. Cecilia; and a third on the Via Aurelia.

Adrian founded Galeria on the Via Portuense; Capracoro, on the Via Cassia; Borghetto, on the Via Latina; and Castel di Guido, on the Via Aurelia.

Boniface VIII., in 1300, founded one at Castel Giubbileo, on the site of the ancient Fidenæ, and another at Capo di Bove, on the Via Appia.

Between the eighth and eleventh centuries others had been founded at Formia, on the Via Nettunese; at the Isola Farnese (Veii), and at Laurentum (see Plate XII.).

The object of these Domuscultæ was twofold: primarily, to bring back the soil to a state of cultivation; and, secondarily, to serve as outposts against the pirates and robbers who still greatly harassed the country. The malaria must have been very much less than now, if it existed at all; for some of these domuscultæ were placed on sites now absolutely uninhabitable in summer. Some of them exist in a decaying condition at *the present day, e.g. Isola Farnese; but they seem to have* more or less failed in their object. The Saracens, the bands of robbers, the perpetual feuds of the Colonna, Orsini, Gaetani, Frangipani, and other great families, paralyzed all efforts at improvement. Works in the Pontine region, fitful and imperfect as they were, represent the only continuous attempts made to control the forces of nature; whilst the deplorable state of agriculture may be gathered from the innumerable efforts made by the Popes to regulate the growth and price of corn,[1] showing that at times the population must have been reduced to the verge of famine.[2]

[1] Nicolai, *Annona di Roma*, vol. ii. *passim*; and Galli, *Cenni statistici sullo Stato Pontificio*, 1840, p. 456 *et seq.*

[2] *Bolla di Sisto Quinto*; Nicolai, *Annona di Roma*, p. 44.

We may sum up the history of the progress of malaria in the province of Rome very briefly as follows:—

The references to intermittent fever in the various classic writers are numerous and definite, showing beyond all doubt a thorough familiarity with the various forms of the disease, and the change from more frequent to less frequent periodicity. But there is no single instance of reference to a locality in which intermittent fever might be acquired, and this is the more remarkable, considering that the phases of an attack of ague are made matters of jest and satire.*

The use of the word "pestilens," applied to various localities, must not be taken to signify universally, infected by malaria, for the word is apparently open to the same interpretation in classic Latin as its adaptation in modern English, and is often to be understood as implying what we may call "the disadvantages" of a damp climate. The prayer to Jupiter in Cato, *De Re Rustica*, cxli., to be spared from *seen* and *unseen* diseases, and the vague foreshadowing of their origin in invisible minute organisms set forth by Varro, Columella, and Vitruvius (*loc. cit.*), and by Palladius, *De Re Rustica*, i., 7, though applied by the writers explicitly to "loca quæ palustria sunt," *i.e.* marshy places; and the obvious meaning of the passage in Strabo (*loc. cit.*), that disease may be acquired in marshy districts, must not be hastily assumed to imply the knowledge, or even the opinion, that malarial disease was associated with marsh land, for, as has already been repeatedly pointed out, *no* specific result of living in a marshy district is ever given, and we have an equal right to assume reference to any form of rheumatic or pulmonary disorder, as to intermittent fever. The failure to connect the locality with a specific disease is the more strange, when we consider how careful and accurate was the observation of some of these writers; indeed, one cannot but feel, after reading their works, how very small in many respects is the interval between their knowledge and ours.

* Juvenal, *loc. cit.*, and Aulus Gellius, *Noctes Atticæ*, xvii. 12, who quotes a passage from some lost work of Plato's, in which the periodicity of a tertian ague is jestingly spoken of as one day of one's mother, and one day of stepmother, and a quartan as one day of stepmother and two of mother—Ἄλλοτε μητρυιὴ μέλει ἡμέρη ἄλλοτε μήτηρ and μία μητρυιὰ, δύο μητέρες.

The theories of Cato, Varro, and Columella, as to the origin of diseases in "animalia quædam minuta," though based upon pure conjecture, had almost as great a justification seventeen centuries since as it has now when applied to intermittent fever. For we must confess, to be strictly accurate, that the proofs of the causation of disease by minute organisms, as studied with all the appliances of the nineteenth century, are exceedingly limited; and the enthusiasm with which the germ theory of *all* disease has been accepted in some quarters is, after all, only a return to the empirical ætiology of well-nigh two thousand years ago. Modern writers on the subject, especially some Italian ones, have cited these passages *ad nauseam*, as a foreshadowing of what they fully believe to be the truth, forgetting that the age in which the great classic authors lived was as much an age of philosophic speculation as the present, if not more so. Those who have to read modern treatises on the subject cannot but feel how great has been, and still is, the influence of the philosophy of the Augustan age. The very authors who begin by summarily rejecting what is known in Italian as the "pregiudizio palustre," only reiterate it under a very thin disguise of modern knowledge, so difficult is it to shake off the beliefs of past ages.

Whatever theories we may hold as to the origin of intermittent fever, we cannot but feel, after this necessarily brief and incomplete sketch of the present state of the province of Rome and the causes which have led to it, that the growth and progress of malaria has been slow in the extreme; that, whatever may be the relation of the disease to the present condition of the soil, the circumstances which have brought about this condition have been almost entirely political, and may be summed up in one word, "neglect," or, if we must qualify it, "neglect of agriculture." Nothing which has been or could be related concerning any given district justifies us in supposing that the malaria has caused the abandonment of the Campagna. On the contrary, in every case which we have examined, we find political causes—chronic insecurity of life and property; war and its attendants, plague and famine,

clearing the ground, reducing the population, and destroying the works of civilization. This accomplished, and the inhabitants reduced to the utmost state of destitution and misery, the soil untilled, the woods destroyed, the water-courses neglected, Nature, uncontrolled, has had her way for centuries, with the result that a land which was the home of the greatest empire the world has ever seen, occupied by a people who excelled in learning and the arts, as in luxury and vice, became a squalid pestilent desert, whose reclamation and restoration to anything approaching its former state will sorely tax the energies and finances of their successors.

PART II.

CHAPTER VIII.

INTRODUCTION.

HAVING discussed the broad features of the problem before us, we will now consider in detail the local conditions under which intermittent fever prevails in the Roman Campagna; the circumstances which determine its localization, and the effect of soil, climate, and population, upon its distribution and intensity. We have established a general relation between altitude, moisture, and temperature, and the disease. We have seen, from the history of its rise and progress in the province of Rome, that in Europe, at all events, it is a strictly endemic disorder, developing itself very slowly, perhaps more slowly than any other known disease, whilst at the same time it establishes itself so firmly as to afford no hope of the existence of a prompt and efficient remedy for the infected areas. The very nature of malaria would seem to indicate that the methods by which it is to be combated must of necessity be as slow in their operation, or nearly so, as the progress of the disease itself. The circumstances under which malaria manifests itself are numerous and complicated to the last degree, and of its precise cause we are as yet absolutely ignorant. On the other hand, we have a very considerable knowledge of the conditions, general and local, which appear to be necessary for its production. We must examine all these conditions carefully, and endeavour to find some one factor common to them all, before we are entitled to say that we have made any real advance towards an exact knowledge of the ætiology of the disease. To assume a

cause, and endeavour to fit the assumption to these conditions, is in the highest degree irrational and mischievous, and has led to the expenditure of an amount of labour and energy out of all proportion to the results obtained. It is hardly possible to conceive a disease the honest investigation of which requires so thorough a knowledge of all and every condition under which it can or cannot exist. Any theory formulated without the strictest regard to these conditions, though it may of course by accident be correct, must *ipso facto* be unsound and unreliable.

We shall find as we go on that from the earliest times to the present day there has existed a belief in its origin in *animuscula quædam minuta;* that is to say, in some minute organism, which, entering the body through the external apertures, gives rise to the well-known symptoms of intermittent fever, in some manner which is as yet unknown, and for which no explanation whatever has yet been offered. The germ theory of disease as applied to malaria is, then very ancient history. It was assumed at a time when no, means existed for proving or disproving it; and not only was it accepted, but it took a clear and definite form in the so-called "pregiudizio palustre," which sought to establish a positive relation between the disease and marshy land, or, rather, the emanations from it. Much, it is true, has been written of late years to show that there is no necessary connection between marshes, as such, and intermittent fever, but the belief dies hard, and those who have taken upon themselves to combat the marsh theory, have but extended the definition of a marsh in order to meet the difficulties raised by advancing knowledge. A much smaller number of writers, mostly with very imperfect information at their disposal, have endeavoured to rise above the stagnant water, and to discover the real constants of the problem, regardless of the conclusion to which their investigations might lead. In the writer's opinion, this is the only rational way in which to arrive at any reasonable result. As a method of research it has few attractions for the modern pathologist, who is but too apt to regard his cultivating-chamber and his

test-tubes of nutrient gelatine as the be-all and end-all of ætiological research. True, it is a line of study which must be pursued, and, rightly carried out, may lead to the most valuable results. But the sequel of our story will show to what absurdities it can lead when relied upon alone as a method of solving the enormous difficulties presented to the investigator of the ætiology of malaria. For these reasons we will rigidly separate the examination of such theories from the investigation of the conditions under which malarial fevers exist, and the circumstances which modify these conditions, and shall in this way place ourselves in a better position to estimate the results of such researches at their true value.

The lines on which our inquiry is to be built have been already roughly traced. It is not difficult to indicate the heads under which this branch of our subject can best be considered. They are the following :—

Altitude.

Local conformation of the soil ; constitution of the soil, and water.

Cultivation.

Meteorology.

Population.

The condition of the people.

CHAPTER IX.

RELATION OF MALARIA TO THE ALTITUDE OF THE SOIL.

IN discussing the distribution of malaria throughout the world, we found that it exhibited an undoubted tendency towards low-lying land, and that in Europe, at all events, almost the whole of the malarious tracts were less than 182 metres (600 feet) above sea-level. Hence we argued a relation between the disease and altitude. We have now to examine this relation in detail, and endeavour to find some explanation for it.

A few examples of the altitude at which malaria may and does prevail will help us to an understanding of the real question at issue.

In Europe it has just been said that 182 metres (600 feet) represents the limit of all the large malarious districts, but there are a number of important exceptions to this rule.

In the Alpine region of Germany, malaria exists at an altitude of 600 metres (1,968 feet).*

In Central Italy, on certain plateaux, among the Appennines this altitude is exceeded. In the Lebanon these fevers are met with at 2,000 metres (6,500 feet). Oldham mentions their existence among the Himalayas at over 2,400 metres (8,000 feet). At Nyun Tal, 1,950 metres (6,400 feet) above sea-level, intermittent fever is the prevailing disease, in wet seasons from

* Hirsch, vol. ii. p. 186.

June to August.[1] In the Peruvian Andes it is found at an altitude of 2,500 metres (8,200 feet); and the table-lands of Mexico, 2,000 metres (6,500 feet), are by no means free from the disease.[2]

Clearly then altitude, *per se*, does not preclude the possibility of malaria; but it will be noticed, that in the cases given, the upper limit rises as the latitude of the locality diminishes, so that there must be some compensating factor which diminishes as the latitude increases for a given altitude. This is not far to seek; and is to be found in the fact that, *cæteris paribus*, the mean temperature for a given altitude increases as we approach the equator. Hence it may be fairly argued that the only relation of malaria to altitude consists in the diminution of temperature which accompanies the latter. We have already seen that, broadly speaking, the intensity of the disease varies directly as the temperature; and were it not for the anomalous examples of malarious districts all over the world, at an altitude much above the mean level reached by the disease in the countries in which they occur, we might dismiss the question of altitude as being of no importance.

Unfortunately the matter is very far from being so simple as it appears to be. A study of it in a malarious country at once reveals the fact that there are local conditions present everywhere which set all preconceived laws at defiance, and the law as to altitude is at once discovered only to hold good when, to use our phrase from Euclid, the mountain and hill country to be compared are "similar and similarly situate." But as this is never the case, we must regard our supposed law in the light of the innumerable exceptions to it which exist.

Let us consider a few examples. An attempt has been made by a Roman engineer to show that, if the line indicating an altitude of 150 metres (492 feet) above sea-level be drawn upon the map of the province of Rome, all malarious localities lie outside it.[3]

[1] *Report of the Royal Commission on the Sanitary State of the Army in India*, ii. p. 199.

[2] Jourdanet, quoted by Oldham, p. 98.

[3] *Giornale del Genio Civile*, 1882, Tavola vii.

In a very general sense such is the case; but numbers of examples of small infected areas above this line might be cited among the valleys in the mountainous districts. The peculiarity of these isolated areas lies in the fact that they *are* more or less isolated, and that apparently similar valleys quite close by are perfectly healthy.

Again, in the Central Appennines, in the district between Isernia, Campobasso and Benevento, there are exceedingly malarious districts much above the level of the surrounding country. Indeed, wheresoever malaria prevails cases of this kind invariably occur. How are they to be explained?

Again, we must seek some factor common to these more elevated localities and the lowlands out of which they rise.

It has already been shown that heat and moisture combined are common characteristics of malarious countries; and we have said that, other things being equal, temperature diminishes as altitude increases. The cases under consideration are precisely those in which other things are *not* equal. Local causes are in operation which serve to maintain those conditions which are necessary for the development of malaria, and more especially temperature and moisture, at all events in temperate and sub-tropical countries. We shall find, when we come to discuss all the circumstances under which malarial fevers may be acquired, that these are places which do not admit of being classified with any which have been mentioned, and that their malarious qualities depend upon conditions in many respects apparently very unlike those already described.

We have thus far considered the relation of malaria to altitude above sea-level. There is another aspect of this question of altitude which may conveniently be discussed here; that is to say, the effect of small differences of level in modifying the intensity of the disease within limited areas.

In the general description of the Roman Campagna great stress was laid upon the fact that it is not a plain; but, on the contrary, is cut up in all directions by narrow valleys of varying depth, the greater number of which have some sort of stream at the bottom. If we turn to the malaria chart of the

province, we cannot fail, as already remarked, to be struck by the way in which the disease follows the course of the streams, which, according to the chart, means that it runs along the bottom of the valleys. That is to say, a difference of fifty or sixty metres (164-196 feet), or even much less, is sufficient to cause a thoroughly appreciable difference in the intensity of the malarial infection of the locality. It might be said, that these distinctions of intensity are arbitrary, and that in the majority of cases there is no positive proof that such is really the case, and that, in reality, it is only a forced application of the law of altitude to differences which are too small to come within its scope.

This is an opinion which might very reasonably be held by those who have never lived in malarious countries, or, having done so, have never been placed in the position of having to choose between the top and the bottom of such a valley, for camping ground.

To suggest to a Campagna shepherd that the difference was immaterial, at all events in the malarious season, would be to court an expression of contempt for the ignorance displayed Though he might admit, that it was in reality a choice between two evils in many cases, he would not hesitate, if it were open to him, to prefer the former; and he would probably assign two reasons for his choice—first, that from the high ground he could the more easily survey his sheep and direct his dogs; and, secondly, that at the bottom of the valley there was an "aria grossa e cattiva," *i.e.* a dense and unhealthy air.

The author has passed many nights in these valleys in the hottest and most unhealthy season of the year; and it must be confessed, that as a rule, the air at the bottom of a valley is hot and stifling, the dews heavy and soaking, and the cold towards morning by comparison intense, whilst above, though by no means warm, the air is fresh, the temperature more equable, and the dew not more than can be easily combated. If there be any wind, and the position of the valley be such as to prevent free ventilation, these differences are greatly intensified, and it may be very cold above all the night through. There is but little doubt

that the opinion of the shepherds is justified by experience, and that, ridiculous though it may seem, in the Roman Campagna at all events, a difference of forty to sixty metres of level, or even less, is always an advantage, and may prove a real protection against disease.

The opinion as to the greater intensity of the infection on low ground is not, however, only based on such experience as this; and, for reasons which will appear later on, it would not be fair to form a definite opinion upon any number of isolated cases of the spending of *one* night in such places, either on high ground or at the bottom of a valley. Permanent residence is the true test; and of this we have a great number of examples all over the Campagna.

It may be well here to give also a few cases of towns which are much above the level at which malaria exists, but whose inhabitants frequently fall victims to it, because their work lies in the plain below.

Rocca Ma'ssima, in the Volscians over against Velletri, is over 700 metres (2,300 feet) above sea-level, and not very much less above the plain. Those of its inhabitants who can afford to stay at home in the mountains escape, but those who descend to the plain below, and not unfrequently remain there for a time, acquire the disease.

Laveran* gives a similar instance: "The town of Constantine, in Algeria, is built on an enormous rock some 600 metres (1,960 feet) above the surrounding country; at 130 metres below (420 feet) lies the valley of Rummel. The inhabitants of the town of Constantine rarely or never are attacked by malarial fevers, whilst those who inhabit the valley as rarely escape. The same is true of Bône; the inhabitants of the town built high up on the hills which border the sea are protected from malaria, whilst those of the lower town still pay a heavy tribute, in spite of the important works which have been carried out, and which have already produced excellent results."

It will be seen from cases of this kind that very great caution is necessary in determining whether a given place is

* *Traité des Fièvres palustres.* Paris, 1884, p. 7.

malarious or not; and that under no circumstances should the mere fact of the existence of disease there be accepted as proof, since it may have been acquired elsewhere.

If we descend to a somewhat lower level, say to Sezze and Sermoneta, we find the same thing on a more extended scale. The towns themselves, though respectively 290 metres (950 feet) and 257 metres (830 feet) above sea-level, are very unhealthy; but still not so unhealthy as the level of the Pontine marshes below them, in which most of the adult male population find their employment. The women chiefly stay at home; those of Sezze are proverbial for their idleness, and it is by no means uncommon to find among them a woman of thirty years of age who has had *three* husbands, all dead of fever. The moral sense of the natives of these towns is so degraded, that the death of a horse or mule is said to be a matter of far greater concern to them than that of a child or relative.*

We have here the strongest possible evidence that, other considerations apart, difference of level of less than 250 metres (656 feet) gives a certain considerable degree of immunity from the disease which infects the plain below.

By far the most interesting cases, however, are those of houses built upon ground but slightly elevated above the general level of the country. As has been said, forty to sixty metres (131 to 196 feet) is about the height of most of these elevations in the Roman Campagna, and in those localities which are inhabited, the usual, if not the invariable, practice is to build the house upon the highest point, and plant the vineyards upon the slopes. An example of this, which we shall have to study very minutely later, is to be found opposite the basilica of S. Paolo fuori le mura, two kilometres (1·24 mile Eng.) from the Porta San Paolo. The house is thirty-eight metres (ninety-eight feet) above the road, which is itself about thirteen metres (forty-two feet) above sea-level, the neighbourhood of the basilica is notoriously unhealthy, and the few inhabitants there are sleep in Rome during the summer months.

During a six weeks' residence in the monastery, in the

* Pinto, *Roma, L'Agro Romano e i Centri Abitabili*, p. 100.

months of July and August 1885, the author had abundant opportunity of observing the progress of the fever among the few that still lingered. The occupiers of this house keep an osteria on the level of the road, and used at one time to live over it; so long as they did so the whole of the family suffered severely from fever, despite the precaution of sleeping as much as possible in the city during the summer and autumn. After a new house was built on the summit of this mass of tufo, the top of which is but thirty metres (ninety-eight feet) above the level of the road, it was found possible to inhabit it all the summer through without any serious risk of illness. Cases of this kind could be multiplied without difficulty; but again experience shows that the benefit obtained is not always as great as might be expected, and this is especially the case when the building is sheltered in any way by neighbouring hills (Plate XIX.).

The next application of the principle is to be found in the houses built on the tombs, as at Casal Rotondo on the Via Appia, at the sixth milestone from the Porta San Sebastiano, and others which have been destroyed in order to preserve the ancient monuments. The height above the ground in this case is not more than fifteen or sixteen metres (fifty or fifty-four feet). Lastly, it is not uncommon to find houses in the Campagna constructed with all the living rooms on the top floor; and it is a matter of universal opinion that the upper story of a house is healthier and safer, as far as malaria is concerned, than the lower, and practical expression is given to this belief by the method of construction adopted. One more instance, which perhaps hardly comes in this category, might be quoted, and that is the custom the shepherds have when they are obliged to remain some time in one place, and are able to do so, of constructing small platforms of wattles raised three or four feet above the ground, with sometimes a roughly thatched roof, on which they sleep at night. Their object is to keep their bodies off the ground at any cost, they themselves saying that though very risky, it is much drier and warmer than sleeping on bundles of twigs on the gound itself.

These customs are by no means peculiar to the Roman Campagna, but prevail in all malarious countries. Wallace (*Malay Archipelago*) describes the houses of the natives in New Guinea as being elevated on poles fifteen or more feet above the ground, and similar practices prevail in Burma, Assam, and parts of Africa.

We have two deductions to make from these facts, both of which are perfectly justifiable. That, for a given latitude, thereis a more or less constant altitude at which malaria ceases, and that this is probably due to a diminution of the mean temperature; that variations from this limit are dependent upon local circumstances and conditions which seem to maintain the temperature of the locality above the average for that altitude and latitude.

Secondly, that from the practical experience of the inhabitants of malarious countries, we are justified in assuming that it is a distinct advantage to elevate the dwelling-house as much as possible above the general level of the soil.*

On any hypothesis which has been put forward as to the causation of malaria, the effect of altitude above sea-level is easily understood; but the undoubted value of a comparatively trifling elevation above a malarious soil is not so readily explained.

We will not here attempt an explanation; but content ourselves with the deduction which we have a right to make, namely, that at a certain, not very great, height above a malarious soil, the risk of acquiring the disease materially diminishes, and ultimately ceases.

* The case of the house at St. Paolo probably involves both these considerations. Its elevation above sea-level can hardly be considered sufficient to materially affect the temperature, so that we should regard it rather as a simple case of elevation above the surrounding country.

CHAPTER X.

RELATION OF MALARIA TO THE LOCAL CONFORMATION AND CONSTITUTION OF THE SOIL AND TO WATER.

HAVING to some extent obtained a vertical limit for the existence of malarial fever, we have now to investigate what may be called the horizontal component in any given malarious district. We have seen good reason for believing that at a certain limited vertical height above the soil all risk of infection ceases; that is, to use a somewhat crude illustration, a person living in a captive balloon at a certain height above the most malarious soil known, and holding no communication of any sort whatever with the earth, would be absolutely safe. We have now to consider what, if any exist, are the horizontal limits of a malarious site. We cannot expect as simple and complete an answer to this as to the former question, nor would it be reasonable so to do. Whatever the nature of the infection, it clearly rises vertically, and unless confined by impervious walls of the requisite height, it must extend itself horizontally. We know this much, that in ordinary cases the infection imperceptibly diminishes, until it disappears entirely, so that whilst we can say definitely that a given place A is deadly, and another place B, ten miles away, perfectly healthy, we cannot define very precisely the boundary line between the two. How, then, are we to proceed in order to discover this horizontal limit?

There is only one test can be applied, and that is the health of individuals having fixed abodes at different points in the area under consideration, together with the experience of

those whose occupation takes them continually to the same places.

In the case of Sezze, the horizontal distance from the centre of the town to a perpendicular line drawn through the nearest point having the mean level of the Pontine marshes, is little more than half a kilometre (rather more than 500 yards); but we are not justified in saying in this case, that within half a kilometre of a place where the infection is comparatively slight, there is another place where it is most intense, because they are not on the same level; and it is absolutely certain that an individual in a captive balloon moored over the Pontine marshes at the same height above sea-level as that at which Sezze stands, would be far safer than if he lived in the town itself, and might even descend much lower, without seriously increasing the risk of malarial infection. We must, therefore, regard the cause of infection as a something which exists in a stratum of limited altitude, which diminishes continually as we ascend from the sea-level, until it vanishes altogether.

As in the previous case, in order to realise the horizontal distribution of the disease, we must study some actual examples, and endeavour from them to discover the conditions which determine its horizontal limits in different localities.

It might be asked, are there any undoubted instances of sudden variations of intensity? To this question one must reply in the affirmative, though the answer is based rather upon general experience than positive knowledge of such cases.

That there are recognisable degrees of intensity within comparatively small areas must be considered as beyond all reasonable doubt; and further, these differences are sufficiently accentuated to make possible the construction of such a chart as that showing the distribution of the disease in the province of Rome. We have now to consider what are the limits within which these differences are recognisable. and how far they are related to the local conformation of the soil.

Our first difficulty lies, as before, in the fact that the country is but thinly populated, and those parts which are of

most interest to us are in many cases devoid of permanent inhabitants. We must, therefore, rely to a large extent upon such information as the experience of those who frequent these places will afford.

If we were to start from almost any of the gates of Rome, and follow the main road for a few miles, carefully examining the character of the land on either side, and inquiring of such inhabitants as we might find, their opinion of the healthiness or otherwise of their immediate neighbourhood, we should be greatly struck by the apparent precision with which they would indicate varying degrees of infection, within exceedingly limited areas. Few or none would be found to admit that the neighbourhood was entirely free from fever, but sharp distinctions as to relative intensity, often extending over but a few yards, would impress the inquirer strongly with the idea, that however loose and inaccurate these statements might be, there was a residuum of fact in them not to be neglected.

The very words used to indicate the more unhealthy sites would after a time produce an impression by their constant repetition: "la giù c'è aria cattiva" (*down* there is bad air); never would the answer be "lassu," *i.e.* "*up* there"; and these remarks will be applied to differences of level apparently quite insignificant. Were we to collect and classify a number of such cases, we should find, that the local opinion, not only confirmed what has been said regarding the relation of the disease to altitude in an extraordinary degree, but that most of the natural consequences of variations of level contributed very materially to the result; that is to say, we should very soon be convinced that there was something more than mere difference of level to be considered. The beds of very tiny streams, perhaps only three or four metres (nine to thirteen feet) below the general level, and not any more in width, will almost invariably be pointed out as especially unhealthy, and any depression of the soil, deep enough to be in any way sheltered from currents of air, or where the soil is of such a character that the bottom is always more or less damp, will be named in the same category. We thus become

aware that over a small area which is unhealthy in its entirety, degrees of intensity are recognised, and that the general conformation of the soil, and the effect of its constitution, and the action of water, in determining that conformation, are important factors in the local distribution of the disease.

Practically, the result of such inquiries, as have been supposed, amount to this, that wherever, by reason of the conformation or constitution of the soil, the drainage is interfered with, and it is possible for water to collect, there will the malaria, in the opinion of the inhabitants of the neighbourhood, be more intense, than in places where the drainage is good and the retention and stagnation of water impossible.

Thus we find the study of small areas entirely bearing out the deductions made from the malaria chart of the world and of Europe, that malaria and wet soils have a close and intimate relationship, and, further, that free access of currents of air to any given locality, is not without effect in diminishing the intensity of the malarial infection.

Examples of these local variations over very small areas will be given in a succeeding chapter; but a few cases of the same thing on a somewhat larger scale will not be out of place here, and will serve to illustrate some of the chief features of a malarious locality, and prepare the reader for a consideration of the multitudinous local conditions which must be taken into account before we can rightly appreciate the difference between such districts, and others apparently very similar in which the disease is unknown.*

In the account of the geology of the province, reference was made to the existence in the Alban Hills, and in the mountains of Bracciano, of extinct craters, which had in their time been volcanic lakes, subsequently drained by natural or artificial means, and now filled more or less completely with

* A minute and detailed account of the tenute of the Agro Romano, containing much valuable information regarding the nature of the soil, cultivation, water, and the degree of malarial infection prevailing in each—will be found in *Annali del Ministero d'Agricoltura Industria e Commercio*, vol. lxxi. ; *Cenni sulle condizioni altimetriche ed idrauliche dell' Agro Romano: Relazione Carnevari.* Roma, 1874.

alluvial soil. These beds of old lakes are almost without exception malarious, and have this especial interest for us, that they are as a rule somewhat elevated, and are generally situated in the midst of otherwise non-malarious country. Some of them are still very boggy, and imperfectly drained, whilst others, probably owing to some natural fissures in their walls, are comparatively dry. The best known of these volcanic basins are the Palude di Stracciacappe and the Valle di Baccano, in the mountains of Bracciano, and in the Alban Hills the Val d'Ariccia, between Albano and Genzano, which latter will serve as an illustration on a large scale of a state of things to be found all over those parts of the Roman Campagna, whose soil is of volcanic origin.

The Val d'Ariccia is an oval basin, measuring roughly 2½ kilometres (1½ miles), by 1¾ kilometres (1·08 mile), and placed with its long diameter practically north and south. At its northern end it is surrounded by high and almost precipitous hills, rising to over 500 metres (1,640 feet) above sea-level, whilst at the southern end its wall is but little above the general slope of the country. The basin itself is filled with alluvial soil brought down by the various small streams which drain into it from the surrounding hills, and is to the eye as nearly level as possible. The walls of the basin are composed of hard lithoid tufo, quite impervious to water, and it is obvious that the water which drains into it can only find its way out through cracks and fissures in them, as the lowest part of the lip of the basin is nearly seventeen metres (fifty-five feet) above the soil which fills it.

On the eastern side of the valley is a stream of sufficient size and force, in winter at all events, to turn a mill. The water of this stream is derived from the drainage of the high land on the northern boundary, and between it and the eastern wall of the valley there is a considerable area of land which is always wet and marshy. Another drain has been constructed across the valley to the lowest point of the lip of the crater, to assist in carrying off the water. The cultivation of the valley at its northern end is varied and extensive, the sloping sides being covered with vines and olives, which

extend nearly half-way round the crater; the centre part at this end grows vines, root crops and patches of grain, and general garden produce; in the wetter part already mentioned, canes for supporting the vines are grown. This kind of cultivation covers about one-third of the total area, the rest is occupied by corn-land and pasture. This distribution of the cultivation naturally leads us to suppose that the soil is much deeper at the northern than the southern end of the valley, and indeed such is known to be the case, the soil diminishing gradually from north to south until on the southern lip of the crater it terminates in the bare rock.

The surface of the whole valley appears to the eye perfectly level, but has in reality a gentle slope from north to south, the amount of which will be evident from the map (Plate XIII.); consequently it is possible for the northern end to be comparatively dry, whilst the corn land and pasture at the southern extremity are almost under water, and in continued wet weather this is often the case. The area of the basin is, as already stated very considerable, and the amount of water which finds its way into it during long rains, is much greater than either the natural or artificial drainage will dispose of; and if we consider the Val d'Ariccia, as an all but impervious, rocky basin, which in fact it is, much deeper at one end than the other, it will be readily understood how any excess of water is likely to distribute itself, and how the southern end should sometimes be wet and the northern comparatively dry.

Local opinion pronounces the malaria which prevails over the whole valley to be most intense at the southern end. The mill and its neighbourhood is regarded as being especially unhealthy, so that, roughly speaking, so far as such opinion is of any value at all, we may say that the intensity of the disease increases as the subsoil water approaches the surface. It may incidentally be mentioned here, that similar cases all over the world point to the fact, that the further the subsoil water is from the surface, the less is the risk of the locality being malarious; whilst, on the other hand, a soil which is water-logged to such an extent as to be *always* visibly covered, is rarely very unhealthy. The very dangerous

soils appear to be these in which, by reason of continual variations in the level of the subsoil water, air is alternately sucked in and driven out. So much is this the case, that Professor Tommasi Crudeli has asserted that this aeration of the soil, however brought about, is a necessary factor in the production of the disease. In the case of the Val d'Ariccia it is not difficult to understand that in broken weather, this respiratory process, if we may so name it, is constantly going on.

The ventilation of the Val d'Ariccia, though perhaps not perfect, and at the northern end altogether defective, does not appear on the whole to be unsatisfactory; still, in summer the air is very hot and stifling, and, being loaded with moisture, very oppressive.

This valley illustrates on a large scale a state of things which, though not visible to the eye, exists all over the Campagna. The subsoil water is often confined in shallow impervious basins of cappellaccio, and in this way localities which would never be suspected of being wet or wetter than the surrounding land, may in rainy weather become quite boggy. The formation of these local impervious depressions depends upon a number of local conditions which are very variable in their occurrence, and help us very considerably to understand why the subsoil water of the Campagna is so exceedingly variable in quantity and erratic in its distribution.

The case we have first considered is that of an unhealthy area of limited extent, placed in the midst of hills which are almost entirely free from the disease. Let us now consider an example of the converse state of affairs, viz. a small healthy area in the midst of very unhealthy country. This we shall find at Tor Pignattara.

Tor Pignattara, the name given to the ruin of the mausoleum of Helena, the mother of the Emperor Constantine—is situated on the Via Casilina, three kilometres (1·86 miles) from the Porta Maggiore, upon ground which rises to nearly fifty metres (164 feet) above sea-level. Around the tomb there is a collection of scattered houses surrounded by gardens and vineyards. The soil is tufaceous, dry, and largely worked for pozzolana. There is very little corn-land, and no

ponds or boggy places whatsoever. The site is an exceedingly pleasant one, and for some centuries has been the inhabited centre of a parish. The number of inhabitants in this centre is from 300 to 400, all employed in agriculture. There are shops in which the necessaries of life are sold; a station of the Royal Carabinieri, and a rural school—all evidences of the comparative healthiness of the locality. It is one of the few spots in the Campagna where there are trees of any size; and the stone pines of Tor Pignattara are well known for their vigour and beauty. As we approach the place from Rome, about 370 metres (400 yards) from the centre of the hamlet, the Via Casilina descends into a hollow, the Fosso della Maranella, which carries a small stream. This valley is notoriously unhealthy, and in late summer has almost as evil a reputation as any part of the Campagna; whilst some 400 yards further along the road, and barely twenty metres (sixty-five feet) above the level of the stream, the inhabitants enjoy comparative immunity from fever. The stream is not regulated in any way, and its bed is full of weeds and mud, with stagnant pools on both sides, which are almost dried up in summer and become foul and offensive. The accompanying map and sections will show far better than words how exceedingly small are the limits between a comparatively healthy and an exceedingly unhealthy spot. (Plate XIV.)

What is the difference between Tor Pignattara and the surrounding country? First, it is a small isolated elevation of the soil, though no higher than many places round about it, if indeed so high, which are not so healthy; secondly, it is well drained and dry; and lastly, it is highly cultivated. Practically the whole difference resolves itself into a question of the distribution of the subsoil water.

The constitution of the soil, assisted probably by the cultivation, and the form and small extent of the area, is such, that the subsoil water finds no obstacle in its course to the lower levels. Whereas in the larger areas, of greater or equal elevation, which surround the site of Tor Pignattara, the drainage is by no means so perfect, and the water, having no proper fall, either descends vertically into the ground until it

can find an outlet, or is detained by a more or less impervious stratum of tufo or cappellaccio, and is only removed by slow evaporation from the surface.

It would be possible to cite scores of examples of this kind, from various parts of the Campagna ; but in every case we should find subsoil water or imperfect drainage presenting themselves as the constant factor. The constitution of the soil may vary; there may be great differences of altitude, and greater differences still in the extent and nature of the cultivation ; but in all we should find, wherever the site is malarious, some evidence of the soakage of the soil, and a want of satisfactory drainage.

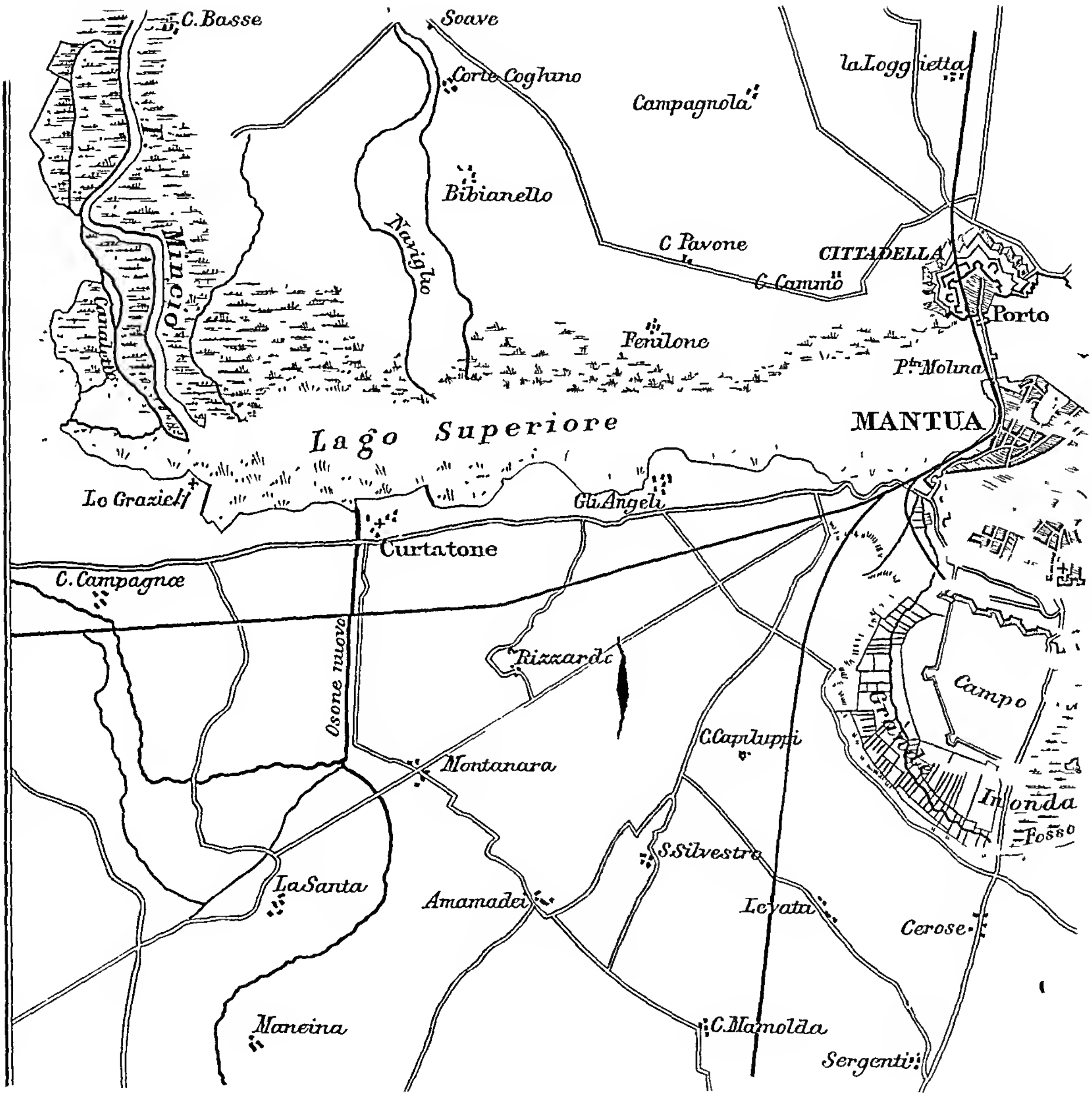
It has been said in the chapter on the relation of altitude to malaria, that the real value of elevation above sea-level was the diminution of mean temperature which accompanies it ; it was further pointed out that, high altitude and good drainage commonly went together, and that, where from some local cause they did not, other necessary conditions being present, malaria might occur.

It cannot be said that difference of mean temperature as affected by mere elevation above sea-level can have any effect whatsoever in modifying the local condition of these isolated healthy spots, so that, from whatsoever point of view we may regard it, the presence of water in the subsoil must be looked upon as constituting the only essential difference. The manner in which this water acts so as to produce differences of local condition, and its more intimate relation to the disease, will be discussed in a later chapter. We will here confine ourselves to a few examples of the relation of water to malaria on a large scale.

The city of Mantua is built in the midst of a malarious district, on the banks of the river Mincio, which, just above the town, widens out and surrounds it upon the west, north, and east sides, forming three lakes, known respectively as the Lago Superiore, Lago di Mezzo, and Lago Inferiore. On the southern and south-western sides is a large area of marshy land which, in case of siege, can be flooded for the defence of the town. (See map Plate XV.)

To face page 114.

MAP OF MANTUA & VICINI



The water in the Lago Superiore is maintained at a constant level by a mole furnished with sluice gates, by which the Valle di Pajolo, as above mentioned, can be flooded in case of necessity, whilst other gates serve to regulate the level of the water in the Laghi di Mezzo and Inferiore. This latter has the river Mincio as its natural emissary, the channel of which having again become constricted opens into the Po below Governolo. The water of the Lago Inferiore is almost at the same level as the water in the Po.

Long experience has shown that when the waters of the Po indicate 1·50 metres (4·92 feet), on the gauge at Governolo, the margins of the Lago Inferiore remain submerged, and there is no fever in Mantua. But when the waters of the Po fall below this level, and the margins of the lake begin to be exposed, there is sure to be an outbreak of malaria in the town.

To prevent this, up to 1848, a movable dam had been constructed at Governolo, provided with cloughs, which could be closed whenever the level of the Po began to fall, so that the water of the Lago Inferiore could be maintained at a constant height. In the year 1848, for military reasons, this dam was destroyed, and the town became subject to continual outbreaks of fever whenever the water of the Po fell below the level mentioned above. From that time till 1866 when Mantua became Italian, and after that date, the inhabitants have urgently demanded the reconstruction of the dam, in order to protect them from the disease.*

The case of Mantua would lead to the conclusion that in a malarious country, *i.e.* in a country in which the conditions necessary for the production of the disease exist, the exposure to the air of a large area of mud is dangerous to health, and rapidly increases malarial fevers. We will not here discuss the reason why, but proceed to consider analogous cases.

Some of the chief malarious districts of Italy are situated on the coast, and though there is little or no tide in the Mediterranean, the land is in many cases so low, that under

* Tommasi Crudeli, *Il Clima di Roma*, pp. 64–65.

the pressure of a suitable wind, the sea often inundates considerable portions of the land, soaking the soil with salt water, and throwing up a quantity of seaweed and other material which, when the wind changes, and the water in consequence retires, is left on the ground to rot, and renders the locality exceedingly offensive.

Whenever this occurs in a malarious locality, at all events in summer, it appears to be followed by an increase of the disease, and so much is this the case, that an idea has arisen and become deeply rooted, not only in Italy, but in England and other countries, that the mixture of salt water with fresh can *per se* give rise to malaria. So strong has been this belief, that in many places in Italy works have been constructed, with great labour and at great expense, in order to prevent these local inundations; and as they have in many cases been attended with good results, this belief has become, if anything, more confirmed. Whereas, as Prof. Crudeli says (*loc. cit.*), the city of Venice, if this theory be correct, should be malarious in the highest degree. Such, however, is not the case; and we must therefore regard the intermittent wetting and drying of the soil as the real cause. In fact, it is but a repetition of the case of Mantua, the fact of the water being salt having no relation whatever to the effects produced. The stench of the decaying vegetable and animal matter probably largely influenced the inhabitants of these localities in their belief.

The case of the marshes near Orbetello practically demonstrates the truth of this interpretation.

After 1860, these marshes were cut off from the sea by means of dams and sluice gates, with the result that there was so much malaria in Orbetello, that the Government were obliged to reopen these communications, and convert the marshes into shallow lakes; and this, while it diminished the disease considerably, enabled the inhabitants to cultivate fish on a large scale, to their great commercial advantage.

The marsh known as the Lago Averno, near Pozzuoli, has been rendered healthy by digging out the bottom, raising the margins, and filling the basin so formed with water, *i.e.*

converting a marsh, the water of which continually varied in depth, into a permanent lake.

The last example which we need take in Italy is that of the Lago di Fucino.[1]

This lake, situated in the Abruzzi country, not far from Avezzano, is of irregular form, and measures about fifteen kilometres by ten (9·32 miles by 6·21 miles), including a considerable amount of marshy land on its margins.

According to Suetonius (*Claudius*, cap. 20), the Emperor Claudius attempted to construct an emissary to this lake, with the idea of taking the water to Rome. But after employing 30,000 men for eleven years in its construction, it does not appear to have ever been used, and was soon blocked.[2] Since the time of the Roman Emperor, many attempts have been made to drain the lake, and reclaim the land it covered for cultivation; but they all ended in disaster to those who undertook the work, until the late Prince Torlonia applied himself to it with the determination, it is said, that "either he would drain the Lago di Fucino, or the Lago di Fucino should drain him." The work was successfully accomplished, and the whole area reclaimed; but among the results was the production of a considerable amount of fever in the neighbourhood. The lowest part of the bed of the lake is about 656 metres (2152 feet) above sea-level; and the mountains which surround it rise to heights varying from 1000 to 1700 metres (3280 to 5577 feet), consequently the local drainage to be provided for is very considerable. But the work has been carried out so satisfactorily, that the health of the villages and hamlets on the low ground around the bed of the lake has improved, and very little fever is now to be found there.

In the Lago di Fucino we have an example of a district high up in the mountains, in which a large irregular lake, with much marshy land around it, and not altogether free from the imputation of being malarious, rendered more so by the

[1] Map at 1 : 50,000, sheets Trasacco, Celano, Civitella-Roveto, and Avezzano; and of the map at 1 : 100,000, sheets Alatri, Sora, Avezzano, and Solmona.

[2] Westphal, *Die Römische Kampagne*, p. 116.

removal of the water, and again becoming more healthy as the drainage became more thorough and complete.

To make our review complete, we should have an instance of a previously healthy, or comparatively healthy, district, rendered malarious by the introduction of an excess of water into the subsoil. Instances of this on a large scale hardly exist in Italy, though when we come to the question of cultivation as affecting the prevalence of malaria, something must be said of the alleged evil effects of surface irrigation. For a good example of the result of soaking the subsoil with water, we must go to India, and in the Jumna Canal we find such an one, on an enormous scale; and though the question is a very vexed one, and in this case has given rise to much discussion, there can be no doubt that a terrible increase of intermittent fever has taken place in the districts through which this canal passes.

The condition of one village is thus described by an executive engineer of the Eastern Jumna Canal:—

"When there was no canal, when the country was dry and parched all round, when higher fields were kept green by water drawn up in bags from a depth of thirty, and sometimes fifty, feet, then Shansi was a pleasant city in a green valley; .... it suffered occasionally from fever. . . . But now that water is plentiful everywhere, and the ground is sodden, the green valley has become a noisome fever bed, and the town is but a crumbling ruin." *

He further describes the people as sterile and dying out.

From reports as to the state of the country in other parts through which canals of a similar character pass, we gather that, wherever the land has been water-logged, and no provision made for subsoil drainage, fever of the gravest type has made its appearance.

From the fact quoted, and countless other examples which might be found, it is, therefore, clear, that a soil which is constantly and completely covered with water, is not malarious; whereas, if the subsoil be water-logged, the worst possible consequences may ensue. It therefore behoves

* *Journal of the Society of Arts*, March 23, 1888, p. 516.

engineers and others who may be called upon to execute the drainage of lakes and marshes in malarious countries, to make ample provision for the thorough and complete drainage of the subsoil. Otherwise, whilst reclaiming land, they may be removing a natural protection against disease, and creating a focus for it which may cause the depopulation of the surrounding country ; and in like manner, the reckless introduction of water into the subsoil, without adequate provision for its removal, may, as in the case of the Jumna Canal, bring about precisely the same result.

The relation of water to malaria may be summed up as follows :—

No soil which is constantly covered by water to any depth is malarious, and the converse would appear to be so far true, that we may say, with a certain reserve, the reasons for which will appear later, that it is highly improbable that any soil which is perfectly dry could be malarious.* Further, in a country in which malaria prevails, those districts in which the subsoil is water-logged will at least be more unhealthy than those in which it is not, the amount of this subsoil water, and the presence or absence of subsoil drainage, determining to a large extent the absence or presence of the disease, and regulating its intensity.

* The oases of the Great Sahara afford a case in point. They contain springs, and are unhealthy, whereas the dry sandy desert is not.

CHAPTER XI.

RELATION OF MALARIA TO CULTIVATION.

THE relation which the cultivation of the soil of a malarious district bears to the disease is of a very complex nature. To discuss it fully would require more space than we have at our disposal, and would involve a number of collateral questions, which, though very important in themselves, have but an indirect bearing upon our subject. We must, therefore, confine ourselves to the discussion of the relation of woods and forests to malaria, and the general effect of the operations of agriculture in increasing or diminishing the intensity of the disease in particular localities.

There are a number of instances throughout the province of Rome, indeed sadly too many, of the destruction of forest; and we may well begin by tracing the results which have followed in some of the more notable cases, reserving for the chapter on meteorology the consideration of the effect of trees on climate, and the relation of climate to the disease.

We have already learned that, although malaria was well known to the Romans, the disease did not attain anything approaching its present degree of intensity in the province, until after the woods and forests, and general cultivation, had been all but utterly destroyed, in the continual wars and internal troubles which have been before referred to as one great cause of the desolation of the Campagna.

We are not as yet in a position to connect this destruction of cultivation with the malaria, in the relation of cause and

effect; but we can say that the malaria followed upon it, and increased in intensity as the destruction and neglect became more and more complete. The connection is, however, sufficiently close to justify us in believing that the cultivation played some part in preventing the spread of malaria, and it is the method and extent of this influence which we have now to consider.

The Romans, down to the later days of the Empire, appear, either from purely religious motives, or from a well-grounded belief in their utility in maintaining the healthiness of the country, to have jealously guarded a number of woods and forests in the province of Rome as sacred to various deities. The exact extent and position of these sacred groves is in many cases doubtful; but a sufficient account of them has come down to us to enable us to form a very fair judgment on this head.

Within the walls of the city itself there were apparently no less than forty-six sacred groves;[1] and though the greater part of them can only have been of small extent, they are evidence of the regard in which trees were held by the Romans.

The number of sacred woods scattered over the Campagna, especially to the south of Rome, was very considerable. Among the more important were the following:—

The Grove of Dea Feronia, near Terracina.[2]

The Grove of Pilumnus, near Ardea.[3]

The Grove of Anna Perenna, along the Mediterranean littoral, in the territory of the Laurentines.[4]

The Grove of Jupiter Indiges—a continuation of the preceding one into the territory of Ardea.[5]

The Grove of Faunus, also near Laurentum.[6]

[1] Pinto, *Storia della Medecina in Roma, al tempo dei Re e della Repubblica*, Roma, 1879, pp. 142–143.

[2] Horace, *Sat.* i. 5–24.

[3] Virgil, *Æneid*, ix. 4, x. 76.

[4] Ovid, *Fasti*, lib. iii. 647; Martial, *Epig.* iv. 64; Macrobius, *Saturn.* i. 12.

[5] Pliny, *Nat. Hist.* iii. 5; Livy, i. 2; Dionysius of Halicarnassus, i.; Virgil, *Æneid*, i.

[6] Virgil, *Æneid*, xii. 766; Horace, *Odes*, i. 4.

The Silva Mesia, near Veii [1]
The Grove of Juno Sospita, near Civita Lavinia.[2]
Silva Dianæ, near Aricia.[3]

The mere names of these woods are of little consequence; the important fact for us is, that a broad belt of woodland stretched from Ostia to Terracina, along the littoral, and from Laurentum to the Alban Hills; and, probably, though our information on this point is not so clear, to a like extent in the northern and western parts of the province; and that whilst these woods flourished, and were kept under control, the malaria was, at all events, not very serious, but *after* their destruction, it increased greatly in intensity.

The relation of forest to malaria may well be studied in the results of their removal or destruction in certain localities.

The effect of stripping the mountains of their timber has been already referred to, and is easily understood. The rainwater, having nothing to detain it, takes the shortest course to the plain, carrying down great quantities of earth, stones, and rubbish, destroying the cultivable soil on the mountain side, flooding the low lands, and rendering large areas marshy and water-logged. But this is not all, trees have a well-known effect upon the rainfall; and their removal from the mountains renders streams which should be perennial, irregular and uncertain, and generally gives rise to a disorganization of the natural drainage, of which the province of Rome affords such numerous examples.

The classic cases of destruction of woods in the province are chiefly in the Pontine region. We will first take that of Cisterna.

The town of Cisterna lies eight miles to the south of Velletri, on the Via Appia, and is almost entirely surrounded by "macchie." In the year 1714, the Caetani family, to whom the greater part of this territory then belonged, proposed to cut down a large area of wood which lay to the

[1] Livy, i. 33.
[2] Livy, viii. 14; Ælianus, *De Animal.* lib. ii. cap. 16.
[3] Strabo, lib. v.; Martial, *Epigr.* xiii. 19.

southwards of the town, and consequently between it and the Pontine marshes. Prof. Lancisi,[1] who was the medical adviser of the then Pope, Clement XI., opposed this scheme with all the weight of his authority, urging that these woods constituted a barrier against the miasmata arising from the marshes, and a protection to the health of the town.

He complained that Gregory XIII., by permitting the destruction of woods which lay between the marshes of Ostia and the city of Rome, had seriously endangered the health of the latter, and for the same reason. His advice prevailed, and the desired permission was refused. But within the first forty years of the present century, despite the protests of the surrounding communes, these woods were cut down, and broad roads made through others in the neighbourhood to the southwards. Fortunately for Cisterna, the prognostications of Lancisi have not been fulfilled, as the following statistics of population will show:—

POPULATION OF CISTERNA.[2]

In 1833	1,691
„ 1853	1,583
„ 1871	3,012
„ 1881	3,096

The death rate from 1834 to 1853 was 4·92 per cent.; from 1862 to 1881, 3·60 per cent.

Clearly, then, so far from suffering by the cutting of these woods, Cisterna has materially benefited.

The urgent complaints of the people of Sermoneta against the destruction of the woods round Cisterna, can only have been based upon an almost superstitious belief in their value as a protection against malaria, and can have had no foundation in fact, for the undoubted rise in the death rate in Sermoneta dates from 1780, whereas the woods were not cut till 1830–40.

[1] Jo. Mariæ Lancisii, "*De Sylva Cisternæ et Sermonatæ nonnisi per partes excidenda Consilium.*" The whole story will be found again referred to in *De Nativis et Adventitiis Cœli Romani Qualitatibus*, by the same author.

[2] *Annali di Agricoltura*, 1884, No. 77, 2nd series, p. 34.

TABLE SHOWING THE RATIO OF BIRTHS TO DEATHS IN THE TOWN OF SERMONETA DURING THE CENTURY ENDING 1869.[1]

Births.	Deaths.	Mean of 10 years ending
74·50	39·50	1779
73·40	106·30	1789
67·10	98·40	1799
64·20	96·40	1809
62·10	74·40	1819
56·30	63·70	1829
59·00	73·90	1839
52·90	79·60	1849
49·90	63·80	1859
43·10	72·30	1869

The terrible rise in the death rate, and progressive fall in that of the births, becomes the more significant when we learn that the present population numbers barely 900 souls, all told. The date of the beginning of this increase of mortality coincides with the beginning of drainage works in the Pontine region. (See p. 84.)

The Commissioners report of Cerveteri, that, despite its notorious unhealthiness, disease has much diminished in the last ten years ; and, though a large area of "macchia" in the neighbourhood has been cut down, they are not able to connect the improved health of the place with its destruction, which occurred many years ago.[2]

At Ischia di Castro, an unhealthy locality to the south-west of Lake Bolsena, in the year 1881, a large "macchia," to the south-east of the town, was destroyed ; but the statistics show no difference whatsoever in the number of cases of fever, the place having for the previous twelve or fourteen years slightly, but progressively, improved in healthiness.

The Commissioners, in their report, give a number of such instances : and we can only here conclude, that "macchie," in many cases, do not only not prevent but may sometimes increase malaria. But we shall presently return to this question.

The only case of replanting worth considering is that of

[1] *Annali di Agricoltura*, 1884, p. 87.

[2] *Ibid.*, 1884, No. 77, p. 39.

Tre Fontane, on the Via Laurentina, four kilometres ($2\frac{1}{2}$ miles) from the Porta San Paolo. Unfortunately, the experiment of the Trappist monks, who hold the estate on condition of cultivating and planting it on a prescribed plan, has been for years the subject of much acrimonious discussion; and the political opponents of the religious bodies have done their best, on the one side, to minimize the value of the results obtained, with the object of ousting the monks from the estate; and the latter, on the other side, have not perhaps managed their affairs so well as to be above complaint. Still, it is a great pity that miserable political considerations should be allowed, as they but too often are, and not alone in Italy, to impede the progress of works of public utility.

The Monastery of Tre Fontane is situated at the bottom of one of the small valleys which have been described as characteristic of certain parts of the Campagna; and so evil was its reputation for malaria, that it acquired the name of La Tomba, or "the tomb." The soil is chiefly tufaceous; but there is a considerable area of alluvium on the side nearest Rome.

The Trappists went there in 1868, and immediately began the planting of eucalyptus, apparently with the idea that the tree possessed some specific power against the malaria, apart from its undoubted capacity for draining the soil. Up to the year 1874, it was found to be impossible to live in the monastery, and the monks returned to the city every night to sleep. In spite of this precaution, they lost twelve of their number in this period.

Under the present Government, the nature of their tenure of the estate has been changed, and they now rent about 500 hectares from the Government, on condition that one hundred thousand eucalypti are planted in ten years. In 1882, more than fifty thousand trees were standing on the estate, and the contract has been since more than fulfilled. The trees have suffered on one or two occasions from frost, to a very serious extent, but the fact remains that the hills around Tre Fontane, which once were utterly bare and uncultivated, are now almost covered with trees and vineyards; and that,

whereas, up to the year 1874, the monks could not live there continuously, they are now able to do so; and though there is still a large number of cases of fever among them, they are rarely, if ever, fatal. Hence, whatever the cause, the place is at least somewhat less unhealthy than it was fifteen years ago.

About the year 1878, a colony of convicts was established in the adjoining valley, on some low land near the Marrana di Ponte Buttero, in order that their labour might be utilized, under the direction of the monks, for the cultivation of the soil and the planting of trees. By this time, the belief that it was possible to live at Tre Fontane, in consequence of the improvements effected by the monks, had gained ground. The convicts were housed in a specially constructed jail, and as far as food and clothing were concerned, were placed in a much better position than the ordinary inhabitants of the Campagna.

Hardly, however, had the fever season of 1880 begun, when almost the whole of the members of the penal settlement fell ill of malarial fevers of a more or less grave type. The explanation offered was, that in that year the malaria had manifested itself on an unusual scale all over the Campagna, and that the atmosphere of Tre Fontane had been exceptionally poisoned by infected air from the surrounding country. Greater precautions were taken for the protection of the colony in the years 1881 and 1882; but in the latter year *every single inhabitant* of Tre Fontane was attacked. Amongst the monks, the cases were, as a rule, slight, but none escaped; some of the convicts, also, had the disease, but very slightly, though many others were attacked by it in the gravest form, the prison guards suffering most severely of all.

The malaria in that year (1882) over the whole Campagna was rather less intense than usual. Clearly, then, the benefit supposed to have been derived from the eucalypti at Tre Fontane, did not extend to Ponte Buttero, barely a mile away; and though Professor Tommasi Crudeli * seeks to deduce from the circumstances of this outbreak, the argument that the

* *Nuova Antologia*, 15 Ottobre, 1884, pp. 662–679.

plantations are of no value, the author must here record his opinion, with all deference to those who were responsible, that the choice of site for the Bagno at Ponte Buttero was very unwise from a purely sanitary point of view, though the watching and care of the convicts may have compelled the authorities to adopt it. It is to be noted, however, that even the most bitter opponents of the monks and their works admit that the convicts suffered more than they, who certainly cannot be said to live a life of ease and luxury under the rule of La Trappe.

Professor Crudeli goes on to say (*loc. cit.*) that the case of Tre Fontane proves to a demonstration that because eucalyptus has been found useful in some parts of Italy, it does not follow that they will succeed in every part ; and adduces the care of large plantations of them in Algeria, by order of the French Government, which have entirely failed to destroy the malarious character of the districts in which they are placed.

Plantations, no matter of what trees, unfortunately grow but slowly, when compared with the urgent necessity which exists for the exercise of their supposed health-giving functions; and it is perhaps a little premature to condemn a plantation of some 60,000 eucalypti, placed close together, none of them more than twenty years old, and the majority not averaging more than five or six years, because it has failed to remove the malaria from a deep valley more than a mile away. For it must not be forgotten, that though the disease still exists around the monastery itself, it has undoubtedly diminished materially since the plantations were made, to the extent of rendering it possible for the monks to reside there all the year round. It would probably be better in this case to accept the facts, without attempting a detailed explanation, for which the data are almost entirely wanting.

Setting aside for the moment any supposed specific action of the eucalyptus, there can be no doubt of the value of trees as a means of sanitation in malarious countries. The reclamation of the Landes of Gascony by Bremontier, who conceived the happy idea of planting them with pines (*Pinus*

maritima), and by so doing not only banished the malaria, but converted a desert into cultivable soil, is probably one of the most remarkable instances of the value of trees for sanitary purposes on a large scale which the world has ever seen. The peculiar nature of the coast in this part of France, exposed to the full force of the Atlantic waves, favoured the formation of shifting dunes of sand, which the wind continually carried further inland, thus gradually destroying the cultivation and converting the district into a vast sandy waste. The structure of the subsoil was peculiar. A few feet below the surface an impermeable layer prevented the surface water from flowing away, and below this was a layer of sand soaked with brackish water, quite unfit for drinking purposes. Under these conditions the whole country became a bog in wet weather, or in the dry season was covered with strings of pools, and the soil of such a character that the shepherds, who formed almost the only inhabitants, were compelled to make constant use of stilts in order to go from place to place in safety.

Two and a half millions of acres on the Biscayan coast were in this state towards the close of the last century; and the scanty population, the scantiest in proportion to area in all France, was kept down by disease and poverty. Malarial fevers of a grave type prevailed throughout the district, and, together with pellagra, rendered the lives of the wretched inhabitants a misery.

Bremontier, in the last decade of the last century, made considerable experiments in planting these sandy wastes at his own cost; and though at first he could obtain no help from the French Government, he ultimately succeeded in persuading the authorities that the work was of real value, and a special tax was imposed, and regulations made for the continuance and completion of the plantations, and the work of reclamation has proceeded in the past half-century at the rate of about 12,000 acres of planting per annum.

The success of the methods adopted has been complete. The sand can now no longer be carried inland by the wind, and the cultivation thus protected by the belt of trees is no

longer liable to be buried and destroyed. Permanent drainage works have thus become possible, the surface and subsoil waters being under more or less complete control; the population has increased rapidly, towns have sprung up, and the once pestilential seaboard has become one of the health resorts of Europe; the malaria and pellagra, instead of being universal, are confined to a few localities, and their complete disappearance appears to be only a question of time. Nor is this all; the planting operations undertaken for purely sanitary reasons have turned out to be a great financial success, and these pine forests produce a very large quantity of turpentine, resin and charcoal; whilst the improvement of the soil inland, consequent upon the planting of the dunes, has enormously raised the value of the land for agricultural purposes; and the once uncultivable waste can now boast of supporting some of the finest vineyards in France.

Comparing the gigantic undertaking begun by Bremontier just a century ago, and the enormous amount of toil and patience which its practical completion represents, with the very small area of land planted at Tre Fontane, and the results there obtained, we cannot but feel that any arguments deduced from the latter experiment, for or against the value of trees in extinguishing malaria, can have but little weight; whilst the undoubted success of the French plantations serves to justify the extension of them on a large scale in the Roman Campagna, and teaches us that though the present generation can hardly expect to see any great and permanent results, the carrying out of such a scheme would confer a lasting benefit on posterity.

We must not, however, assume that the eucalyptus is the best or most profitable tree for the purpose; on the contrary, there is much evidence to show that it is not. But the pine forests which flourished in the Roman Campagna in the later days of the Empire could be restored. The unwholesome "macchie" destroyed, the present alternations of flood and drought corrected, and the vagaries of a desert climate brought under control, there would be food and shelter for the cattle, and the necessity of driving the flocks and herds to

the mountains on the approach of summer would cease, to the great benefit of their owners and the people who depend upon them for food; and beyond this, there would be the enormous advantage of rendering the lowlands cultivable and habitable, thus relieving a large proportion of the population of the Campagna of the present necessity of living in the mountains, and consuming the greater part of their time and energies in long and weary journeys to and from their work.

The whole question of the relation of trees to the disease is complicated and difficult in the extreme. We have thus far dealt with them in purely general terms; and whilst we are bound to admit that enormous benefit has accrued in certain districts from the planting of trees, the results which follow are exceedingly various and complicated, and it becomes difficult to assign to the plantations the precise part played by them in the work of sanitation.

There are, however, some points on which we can form a tolerably definite opinion.

First, then, the supposed fever-destroying capacity of the various species of *Eucalyptus Globulus*. If this exist at all, it is most certainly *not* due to any antiseptic exhalations from the trees, for fever prevails in Queensland in the midst of primæval forests of Blue Gums. No argument based on this theory is therefore of the slightest value.

Secondly, it will be observed that in all the cases quoted of the extirpation of woods, they are described as "macchie." A general description of a "macchia" has already been given and need not be repeated. The fact being that, with the exception of the pines of Castel Fusano, and the few beeches and chestnuts in the mountains, there is hardly a wood in the ordinary sense of the word in the whole province. These "macchie," according to their density and the nature and position of the soil on which they grow, may be either tolerably dry at the bottom or wet and boggy; and there can be little doubt that, in many cases, they themselves contribute in no small degree to the unhealthiness of a district; and the great macchie, or selve, as they are called, of Nettuno and the neighbourhood, are undoubtedly responsible to a large extent

for the extraordinary unhealthiness of the district.[1] Considerations of this kind help us to understand the great diversity of opinion which has existed for centuries, and still exists, on the desirability or otherwise of destroying these "macchie." [2]

In many cases, the exposure of the soil to light and air, with some little artificial assistance in the shape of surface drains, will suffice to render it dry and cultivable; whilst in others, where the subsoil is waterlogged by springs, or from other causes, it is difficult to drain thoroughly, and remains wet and marshy even after the covering of wood is removed. It is not, therefore, difficult to suppose, that in the first case, the removal of the "macchie" might be productive of permanent benefit; whereas in the second, so far from doing good, positive harm might result from the exposure of a sodden soil to the direct action of the sun's rays.

The fact is that the relation of trees to malaria is strictly parallel with their action upon climate, a subject as yet but imperfectly understood, and whose complications and ramifications are so great that it is impossible to give even a summary of them here.

The great function of trees seems to be that of equalizers of temperature and moisture. They prevent undue evaporation and radiation, and by consuming the subsoil water for their own purposes, are powerful instruments of drainage; whilst, by the exertion of their respiratory functions, if we may so call them, they promote a constant exchange of material, and purify and revivify what might otherwise be a stagnant, devitalized atmosphere. Nor is this all. The dead leaves and twigs which fall to the ground annually produce a most valuable addition to the soil, and as certain genera and species of trees will grow where no other form of vegetation can be persuaded to exist, plantations of these species afford a sure though slow method of reclaiming rocky and sandy soils, and bringing them under crops. Lastly, trees are invaluable as barriers against wind, and the shelter afforded by very insignificant plantations will often permit of the cultiva-

[1] *Annali di Agricoltura*, p. 77. [2] *Ibid.* p. 13.

tion of remunerative crops in places which, if devoid of trees, would be absolutely uncultivable.* These may seem to the reader to be but trite and well-known facts; and yet, though the knowledge of them be almost universal, it is but too often acquired by an experience of the effects of the loss and destruction of the trees. The time required for their growth, and the fact that he who plants rarely lives or can hope to live to see the full results of his labour, seems to operate, as might perhaps be expected, against the afforesting of treeless countries; and the undoubted truth contained in the old farmer's advice, "to be aye planting a tree, for it grows when you're asleep," is but too often disregarded because the result is not sufficiently obvious.

The sacred woods of the Romans were probably real woods containing trees valuable for their timber, and maintained as such. When these were destroyed in the troubles which overtook the Empire, the trunks were probably either cut or burned and the butts left on the ground, and from these—in those species in which such mode of growth is possible and from scattered seed, have grown up others, which have never been allowed to attain the dignity of a tree; but have instead, covered the ground with a dense scrub, yielding nothing worthy of the name of timber, in the ordinary sense of the word.

Something of the same kind has happened in various parts of England; good examples of which may be seen in Surrey and Hampshire, where what was once a forest, of fine oaks, yielding valuable timber for ship-building, is represented by scrub oak, hardly worth cutting for firewood and this entirely from the neglect of the most ordinary rules of forestry.

The theory held by Lancisi and others, that a wood, of whatever nature, acted as a barrier, or filter, or screen, against some particulate poison borne by the winds from marshy districts, has taken a firm hold, and prevails largely at the

* "Rainfall, Water Supply, and Storage," by Professor Ansted, *Journal of Royal Agricultural Society of England*, 2nd series, vol. iii. p. 65; and "Cultivation of Waste Lands on Mountain Sides," by T. A. Slater, *ibid.* vol. iv. 2nd series, p. 423; are papers which contain interesting matter in this connection.

present day. But, despite the general belief in its truth, it has never, in Italy at all events, availed much to save the forests from destruction; whilst it has undoubtedly interfered with the removal of pestilent "macchie," whose only value consisted in the charcoal and firewood they supplied. That the theory itself has little or no foundation in fact, is abundantly proved by such cases as that of Cisterna, in which by the destruction of "macchie," the road was laid open for anything borne by the wind from the Pontine marshes, and yet despite this the health of the town has improved. There are, besides, many other instances of woods intervening between a village and a pestilent marsh without producing the slightest influence on the sanitary condition of its inhabitants.

But the relation of trees to winds is not altogether of the simple character imagined by those who support the Lancisian doctrine. The researches of Bremontier,* have demonstrated, that when the wind meets an obstacle such as a wood, it takes an upward course, passes over it, and descends again to the level on the other side, at a greater or less distance according to the pressure; so that, in any case, the action of a wood, as a barrier or filter, can only extend over a very limited area; for the height of any ordinary wood, and stil less of the "macchie" of the Roman Campagna, is very insignificant when compared with the depth of the stratum of air moving before a wind capable of being felt over any considerable area.

Further, if we accept the Lancisian theory of the transportation of malarial poison by the wind, there should be a clear and distinct connection between the direction of the wind and the localities affected. Numberless observations to this end have been made, with the result that there is no proof whatsoever that such relationship exists.

Putting aside all theories as to the origin of the disease, and reducing the problem of the bearing of trees upon malaria to its simplest form, we find, that whenever trees can assist the drainage of the soil, they will at least do no harm,

* *Mémoires de la Société d'Agriculture de la Seine*, tome ix. p. 414, *et seq.*

and may afford great benefit. But when their presence tends to the collection of water, they are harmful, and should be destroyed or so controlled as to prevent this effect. This is, however, hardly possible in the case of true forest trees, and applies almost exclusively to the unregulated "macchie."

So far trees. Let us now turn to the effect of other kinds of cultivation in malarious districts. Beyond the fact that extensive and careful cultivation of the soil in general appears to diminish the malaria, there is no special crop which can be said to have any very definite influence. Large plantations of sunflowers have been tried in various parts of the world, and with very varying success, the object being to cover the soil quickly with a more or less luxuriant vegetation, and assist the evaporation of its water by natural means, in those cases in which the expense of artificial drainage would be too great.

Nicolai* speaks of the improvement of some of his own land, close to the Porta S. Paolo, on which his tenants at first could not live, but which became habitable after a year or two of diligent cultivation; and instances of this kind are not uncommon throughout the Campagna.

The removal of crops from the ground is often followed by an increase of existing malaria; and though some would attribute this to the vegetable *débris* left behind, these are two other possible explanations far more satisfactory and probable. The first is, that on the removal of the vine leaves or the grain, the soil is more exposed to the sun, and radiation consequently more pronounced, and the second, only too probably the real one, is, that from harvest to vintage, and a little later, is the usual fever season, and that the removal of the crops may be a mere coincidence, with little or no effect upon the production of the disease, whilst the number of persons exposed to the risk of acquiring it is very considerable.

The real relation of cultivation to malaria, however, consists, not so much in the nature of the crops grown, as in the agricultural operations necessary for their production—the

***Annona di Roma*, iii. 234.

ploughing, digging, and trenching, and the subsoil drainage, which latter is unfortunately but little used in the Roman Campagna. All these operations tend to ventilate and dry the deeper layers of the soil, to equalise the distribution of subsoil water, and increase the activity of the oxidation processes going on in the soil. Not only this, on estates where high cultivation prevails, the natural drainage is attended to, ditches and watercourses are periodically cleaned and obstructions removed, so that soil and water are kept in a state of continual activity; and beyond all doubt, it is this free circulation of air and water in the soil which constitutes the important factor in sanitation by cultivation.

In malarious countries it has been observed that the breaking up of a virgin soil, or soil which has been for centuries uncultivated, is very frequently followed by an outbreak of fever in the neighbourhood of the operations, which may be severe, but passes away; and if the cultivation and drainage be persisted in, will in most cases, not recur. The disturbance of old "made" soils appears also to be frequently attended by the same result, though in these cases the effect would seem to be more transitory.

So far, then, as the facts before us will permit the formation of an opinion as to the nature of the relation of cultivation to malaria, it would appear that this relation consists in the effect produced upon the quantity and distribution of the subsoil water; and, speaking generally, we may affirm that cultivation will be beneficial, or the reverse, just in so far as it promotes the drainage and ventilation of the soil.

One method of cultivation and its effects remains to be mentioned, namely, irrigation. The results of the construction of the Jumna Canal have already been referred to and discussed, under the head of the relation of water to malaria, and the use of water in large quantities for the purposes of cultivation, practically brings us to the same question again.

Irrigation in the ordinary acceptation of the term, means the conduction of water on to land, by means of canals, dykes, ditches, and the like, *under control*. This control is

unfortunately the most important factor, and in a large number of cases is entirely wanting. Irrigation, properly carried out, and with every precaution taken to prevent the waterlogging of the subsoil, does little or no harm; whereas, irrigation by inundation, as is unfortunately too often practised, may lead to the most disastrous results. The Commissioners, in their report on the malaria of the Roman Campagna, record continual complaints from the inhabitants in the neighbourhood of irrigation works, in which outbreaks of fever are accounted for by the use of water for cultivation, without any attempt at inquiry or justification in particular cases; in fact these complaints are but the expression of a popular opinion on the subject. There is, however, but little doubt that in some instances, the want of proper care for the subsoil drainage has rendered irrigation a very doubtful advantage, and possibly has augmented the already existing malaria. Beyond this, as far as the Roman Compagna is concerned, it would be difficult to express an opinion.

From these considerations, it is clear that the cultivation of a malarious country requires to be carried out with care and judgment; otherwise it may only result in making bad worse. The methods adopted by the *contadini* of the Roman Campagna for the cultivation of the soil are still of the most primæval simplicity, and would probably elicit an expression of contempt from the authors of the classical treatises, *De Re Rusticâ*. The plough used by them to-day is as far as can be made out, identical with that described by Virgil,[1] and, carelessly used, it does little more than scratch the surface of the soil. The use of manure is almost unknown, except on the estates of wealthy proprietors, who make use of the best modern methods of farming. The return of corn in some districts per unit sown is positively ridiculous, and on the authority of the Agricultural Commissioners often barely repays the cost of cultivation.[2]

[1] *Georgics*, I. Cf. *Inchiesta Agraria*, vol. xi. fasc. 1, p. 322. [2] *Ibid.* vol. xi.

CHAPTER XII.

RELATION OF MALARIA TO CLIMATE AND METEOROLOGY.

WE have already had more than enough evidence before us to show that the distribution and intensity of malarial fevers is very largely controlled by those natural conditions which together make up what is known as climate. Further, we have similar evidence that local conditions prevailing over very small areas have a profound influence on the occurrence of the disease.

Continuing on the lines on which the subject has been treated thus far, and descending from the general to the particular, we shall proceed from the consideration of climate generally in its relation to malaria, and as we narrow the scope of the inquiry, shall find it necessary to study the climate and meteorology of exceedingly limited areas, covering in some cases only a few acres of ground. We shall find ourselves confronted with a series of facts and details, the true meaning and significance of which is but imperfectly understood; inasmuch as the question of local climate, *i.e.*, the climate of very limited areas, has been but little studied, although it is of undoubted importance in all sanitary inquiries of this nature.

Thus far we have treated temperature and water as factors in the production of the disease, in a very wide and general sense. Rightly to understand their mode of action, we must enter into detail as to the effect of seasons of the year, rainfall, temperature, and atmospheric moisture. It will

be convenient to discuss them separately in the following order :—

SEASON OF THE YEAR.

Throughout the world, wherever malarial fevers prevail, there is always one period of the year at which the infection, whatsoever its nature may be, attains a maximum of intensity, and this is known universally as *the fever season.* That it should be possible to designate any part of the year by such a title is a fact of very great importance in the study of the ætiology of the disease, the real significance of which appears never to have been thoroughly appreciated.

Malaria we have found to be most intense in the tropics, that is to say, in hot climates. Carrying this apparent relation of temperature to the disease a little further, we may very naturally conclude that it should, even in the tropics, be most intense in the hottest season of the year. A brief examination of the period of the fever season in different parts of the world will enable us to realise how far this is the case.

In temperate and subtropical Europe, the fever season extends over the summer and autumn ; but the infection is not equally intense over the whole period. The beginning of summer, *i.e.*, the beginning of continuous heat after the spring rains ; and again, the commencement of the rains of autumn, about the middle or end of August, generally falling in the hottest weeks of the year, are especially malarious seasons ;[1] whilst a long-continued, dry heat, such as is generally experienced in June and July, appears to diminish the number of cases very materially.[2] There are thus two maxima, one in late spring or early summer, and one in autumn—a marked diminution in the hot weather and a minimum in winter.

[1] In the summer of 1834 the Austrian army had 50,000 men ill of fever instead of 5,000, the mean annual number. This army, quartered in cantonments in the malarious districts of Hungary, was exposed to the full effects of the exceptional heat of the summer of that year.

[2] Aestas callida et sicca Romæ perpetuo salutaris. Doni. De restituendâ salubritate Agri Romani.

The following table shows the proportion of cases of fever throughout the year in different latitudes in Europe.[1]

Month.	Sweden.	Dithmarsch	Leipsic.	Szent Miklos.	S. Giovanni (Rome).	Algiers.
Jan.	3,149	198	68	234	75	
Feb.	3,432	212	118	161	70	35
Mar.	5.428	490	341	204	113	
April	8,138	748	794	538	106	
May	8.567	790	1,292	714	98	202
June	4,889	490	1,147	512	82	
July	2,867	326	679	566	231	
Aug.	2,749	1,182	446	963	303	796
Sept.	3,731	1,318	290	795	307	
Oct.	3,779	596	100	561	202	
Nov.	3,399	432	63	398	141	455
Dec.	2,881	212	46	274	78	

As we approach the tropics, and the seasons begin to divide themselves more and more sharply into wet and dry, cold and hot, the fever follows the variation of climate, and the maxima are found at the periods of transition from hot to cold, and dry to wet. The setting in of the monsoon in India, for example, is always accompanied by a great increase of fever, which is well illustrated by the following figures from Hirsch, vol. i. p. 177.

Month.	Hyderabad (1).	Madras (2).	Deccan (3)
January	955	4·8	6·34
February	821	2·7	5·53
March	956	4·1	6·30
April	994	4·9	6·68
May	896	8·6	5·99
June	758	8·1	5·15
July	1,256	7·5	8·45
August	1,719	14·8	11·65
September	1,861	17·0	12·56
October	1,668	12·9	11·12
November	1,561	8·8	10·42
December	1,464	5·8	9·81

[1] From Hirsch, *loc. cit.* i. 177, and Professor F. Scalzi, *La Meteorologia in rapporto alle Febbri Malariche, &c.*, p. 20.

(1) Average of five years' observations.
(2) Percentage of cases of fever, five years' observations.
(3) Ditto, ten years' observation.

Not only is it true, therefore, that throughout the world the intensity of the disease varies with the mean annual temperature, but it varies also with local changes of temperature.

If this be true generally, the intensity should also vary from year to year, according to the climate of each annual period. That this is the case, the following examples clearly prove :—

RETURN OF CAMPAGNA LABOURERS ADMITTED TO THE HOSPITAL OF SANTO SPIRITO IN ROME.[1]

Year.	Sick males.	Deaths.
1877	7,630	424
1878	7,308	321
[2]1879	11,827	558
1880	9,858	641
1881	6.536	378
1882	4,614	275

ADMISSIONS TO THE HOSPITAL OF SANTO SPIRITO IN ROME FOR INTERMITTENT FEVERS.[3]

Months.	Years					
	1864.	1865.	1873	1874.	1877.	1878.
Jan.	284	195	853	595	638	661
Feb.	228	198	681	528	519	543
Mar.	189	170	711	747	544	502
April	168	151	653	675	564	576
May	112	114	669	584	480	504
June	83	88	409	331	339	375
July	439	340	1,130	865	1,858	398
Aug.	1,492	570	2,824	2,647	2,373	1,604
Sept.	1,056	476	2,185	2,019	1,995	1,896
Oct.	775	437	1.761	1,732	1,460	1,495
Nov.	431	275	1,280	1,186	795	1,245
Dec.	271	205	777	773	695	1,193
	5,528	3,219	13,933	12,682	12,261	10,992

1 *Inchiesta Agraria, vol. cit.* p. 790.

2 By far the greater part of the admissions were for malarial fevers.

3 Scalzi, *op. cit.* p. 21.

The following table is of interest as showing the great difference which obtains between the number of admissions in consecutive months—June, July, and August:—

ADMISSIONS OF CAMPAGNA LABOURERS TO THE HOSPITAL OF SANTO SPIRITO IN ROME.

Year.	June.	July	August.
1877	228	1,207	1,188
1878	345	954	937
1879	205	715	1,556
1880	519	1,002	1,380
1881	234	595	939
1882	196	513	564

When we remember that the total number of agricultural labourers, having either a fixed or temporary residence in the Agro Romano is only some 15,000, these figures assume a terrible significance. In certain notorious years as many as 30,000 cases have passed through the Roman hospitals, which, considering the population from which they are drawn, means a large number of re-admissions. Indeed, the bulk of the cases treated in the last three months of the year *are* what are known as "recidivi," or relapses, the same individual often being re-admitted two or three times in the same year for fever; and in these bad years the resources of the Roman hospitals are sorely strained to provide for the enormous number of cases suddenly poured into them.

Malarial fever is, then, beyond all doubt intimately related to season of the year, and, moreover, varies very greatly in intensity in the same place and in the same season of different years. An examination of the circumstances attending some of these cases of exacerbation will help us further to connect the disease with meteorological phenomena.

In the autumn of the year 1869 an outbreak of malarial fever occurred in the Punjaub, concerning which the following particulars are given by Dr. Oldham* :—

"The influence of a sudden change to cold, from great and continued heat, was well shown in the circumstances attending the outbreak of malarious fever in Northern India last autumn" (? 1869).

* *What is Malaria?* London, 1871, pp. 76–77.

"This fever appears to have prevailed most extensively in the Punjaub, where also the climatic peculiarities alluded to were most marked. It was most severely felt, as autumnal fevers always are, in damp and low-lying districts; but other and healthier localities did not escape. The hot season had been unusually severe and protracted, the natives saying they had never felt such heat; and the rains, at the usual season were so scanty, that scarcity arose, amounting in some districts to famine. At a very unusual period heavy rains fell; and, owing to the lateness of the season at which this occurred, the sun was not sufficiently powerful to thoroughly dry and warm the earth; in consequence of this, there ensued a very damp and chilly autumn and a severe cold season. In fact, the peculiar characteristics of autumn were exaggerated to an intense degree, and were attended by such a prevalence of malarious fever as had not occurred for many years; which being general over a very great extent of country, could not well have been owing to any but climatic causes.

"So intense was the cold in the Punjaub, at the time when people were dying in numbers from this fever, that the thermometer at night fell several degrees below freezing point.

"In one small town, of 8000 inhabitants there were 700 deaths from fever, and nearly the whole population was attacked.

"In the moist and highly cultivated, but generally healthy, Kangra valley, the sickness was so great, that as the natives expressed it, 'all those who were well were employed in drawing water for the sick.' The tea planters were unable to procure labour, and the native cultivators could scarcely till their land. It is officially stated, that this fever 'numbered tens of thousands as its victims' (*Punjaub Jail Report*, 1869). The poorer classes suffered more than the richer and better clad. The rural population was attacked more generally than the people of the large towns; and natives of India more than Europeans. The latter, owing to the superiority of their clothing and houses, their habits of life, and their adaptation to a cool climate, being more capable of resisting the effects of chill and damp, seldom suffer so much as the people of the country from cold-weather fevers.

"In India and other tropical climates it seems that any irregularity in the usual course of the seasons is productive of malaria. If the hot season be protracted, or if the cold season be more severe than usual, malarious fevers are prevalent; but when both are greatly exaggerated, these diseases become epidemic.

"In the years 1809, 1810, and 1811, an outbreak of malarious fever occurred in Coimbatore, Madura, Dindigul, and Tinnevelly, which carried off over 106,000 people. A medical committee was appointed to inquire into the origin of the epidemic; and from the report of this committee it appears that the years 1804, 1805, and 1807, were very dry and hot, and the years 1808 and 1809 were very wet with cold winds. To these variations of climate the natives ascribed the sickness. 'February, March, and April,' the Report states, 'were the worst months, when the heat by day was very great and the ground still damp. As the season

became hotter, the fever was more apt to put on a remittent form, than at an earlier period, when the rains were falling and the atmosphere was comparatively cool.' In other words, when the days were very hot and the nights raw and humid, the fever was more severe than when the climate was cooler and more equable.

"On this, as on other similar occasions, there was also great mortality amongst the cattle.

"In hot climates, places noted for great and sudden variations of temperature are often highly malarious, though free from swamp. Thus the large military station of Kamptee, which enjoys the evil reputation of being the hottest place in India, is also one of the most unhealthy. Yet, the site of the station is remarkably free from all supposed sources of malaria, and so is the neighbourhood. The ground is undulating, elevated, and open. There is no marsh. The banks of the small river Kunnan, which runs past the station, are either perfectly bare of trees and vegetation, or are cultivated with the dry grain crops of the country. The bed of the river is rocky and sandy. The jungles which have been accused of causing the malaria, are at a distance of fifteen to twenty miles from the station; and during a great part of the year the wind blows from the opposite direction. The soil is the black volcanic earth of that part of the country, consisting chiefly of decomposed trap; it absorbs heat greedily, radiates it rapidly, and is very retentive of moisture.

"The climate is remarkable for extremes of temperature. There are heavy dews; and in the cold season, hoar frost is formed. The thermometer during the period ranges from 36° to 110° F. in the shade out of doors; and in the hot season, *in a good house, shut up*, it varies from 96° to 104° F. The temperature of the barracks is, of course, much higher. In the open air the thermometer rises to 140° F. The cold months are the most unhealthy, 'and fevers and bowel complaints are not only more numerous, but also more severe, and generally more fatal, during this season of the year;' fevers are, however, prevalent towards the end of the hot weather (in May and June), and throughout the rainy and autumnal periods. (*Madras Topographical Reports*, 1844.)

"During ten years, the average sickness amongst the white troops at Kamptee (including a small force on the rocky hill of Seetabuldee, near Najpore) was 241·194 per cent.; and amongst the native troops, 62·387 per cent.; chiefly from fevers, dysentery, and hepatitis."

Dr. Oldham further calls attention to the settlement of Singapore (*loc. cit.*, p. 81):—

"Hot and moist, surrounded by salt marshes, and a profuse tropical vegetation, (it) might be expected to be a hot-bed of 'paludal poison;' but far from this being the case, it is noted for its exemption from malarious fevers. (*Report of Royal Commission on Sanitary State of Army in India*, ii. 507.) The explanation of this is to be found in the extraordinary equability of the climate. We are told, that 'from the

temperature being so uniform throughout the year, Europeans are remarkably exempt from the sudden and severe attacks of the disease so common in Hindustan, but owing to the absence of a cold season the climate is not well adapted to men who are much reduced in health and strength.'" (*Report of the Royal Commission*, ii. 595.)

There is one well-known example of the absence of malaria in the tropics, and that in a country where all the conditions popularly connected with malaria exist in an exaggerated degree, namely, the banks of the Amazon in South America. Swamps and virgin forests of enormous area border the river, and yet, on the testimony of Bates, the Amazon is peculiarly healthy. Not so its tributaries, however. But the only difference between the main stream and its branches appears to be that the former is swept regularly after mid-day by a strong wind from the sea, strong enough to enable one to sail against the stream for 750 leagues; whereas the tributaries, owing to their direction, are not affected by this breeze. The result being that on the main stream the temperature is equable, and the "decrease of temperature at night never more than a pleasant coolness."[1]

But on the Tapajos, Bates observes :—

"The mornings, for two hours after sunrise, were very cold; we were glad to wrap ourselves in blankets on turning out of our hammocks, and walk about at a quick pace in the early sunshine. But in the afternoon the heat was sickening.[2] . . I began now to understand why the branch rivers of the Amazon were so unhealthy, whilst the main stream was pretty nearly free from diseases arising from malaria." And again, (xiii. 438) he says—"Notwithstanding damp and mosquitos, I had capital health and enjoyed myself much at Fonte Boa; swampy and weedy places being generally more healthy than dry ones, on the Amazon, probably owing to the absence of great radiation of heat from the ground."

These instances will suffice for the tropics. Let us now take an example from the province of Rome.

The total number of fever cases treated in the hospitals, military and civil, together with those treated at their own

[1] Bates, *Naturalist on the Amazon*, vii. 163.

[2] *Ibid. loc. cit.* ix. 251.

homes by the district medical officers, in Rome from 1871 to 1882 was as follows :—

Year.	Number of Cases treated.
1871	11,355
1872	19,232
1873	21,907
1874	20,286
1875	14,156
1876	17,588
1877	16,761
1878	18,875
1879	34,217
1880	22,699
1881	20,376
1882	19,704

This table points to the year 1879 as remarkable for an extraordinary increase in the number of fever cases, amounting to little short of double the total of the preceding year. Returns collected by Professor Tacchini show that this increase of fever in 1879 was general throughout the whole Campagna, and can only be attributed to one general cause.

The returns referred to* are derived from sixty-one communes, and, with very few exceptions, all show a diminution of fever in the year or two years preceding 1879. Further, the returns of the Hospitals of San Giovanni (female) and Santo Spirito (male) show that the increase was greater among the men than the women, which tallies with what has been before said respecting the greater exposure of the former to the conditions under which the disease may be acquired.

The great variation in the intensity of the fever from year to year is perhaps better shown by the percentage of cases to population, calculated for the third quarter of each year for the sixty-one communes from which Professor Tacchini was able to obtain returns. The figures are as follows :—

* Curves showing the variations in the number of cases of fever in the years 1871–82 for five communes will be found in Plate XVI., Nos. 1 to 5.

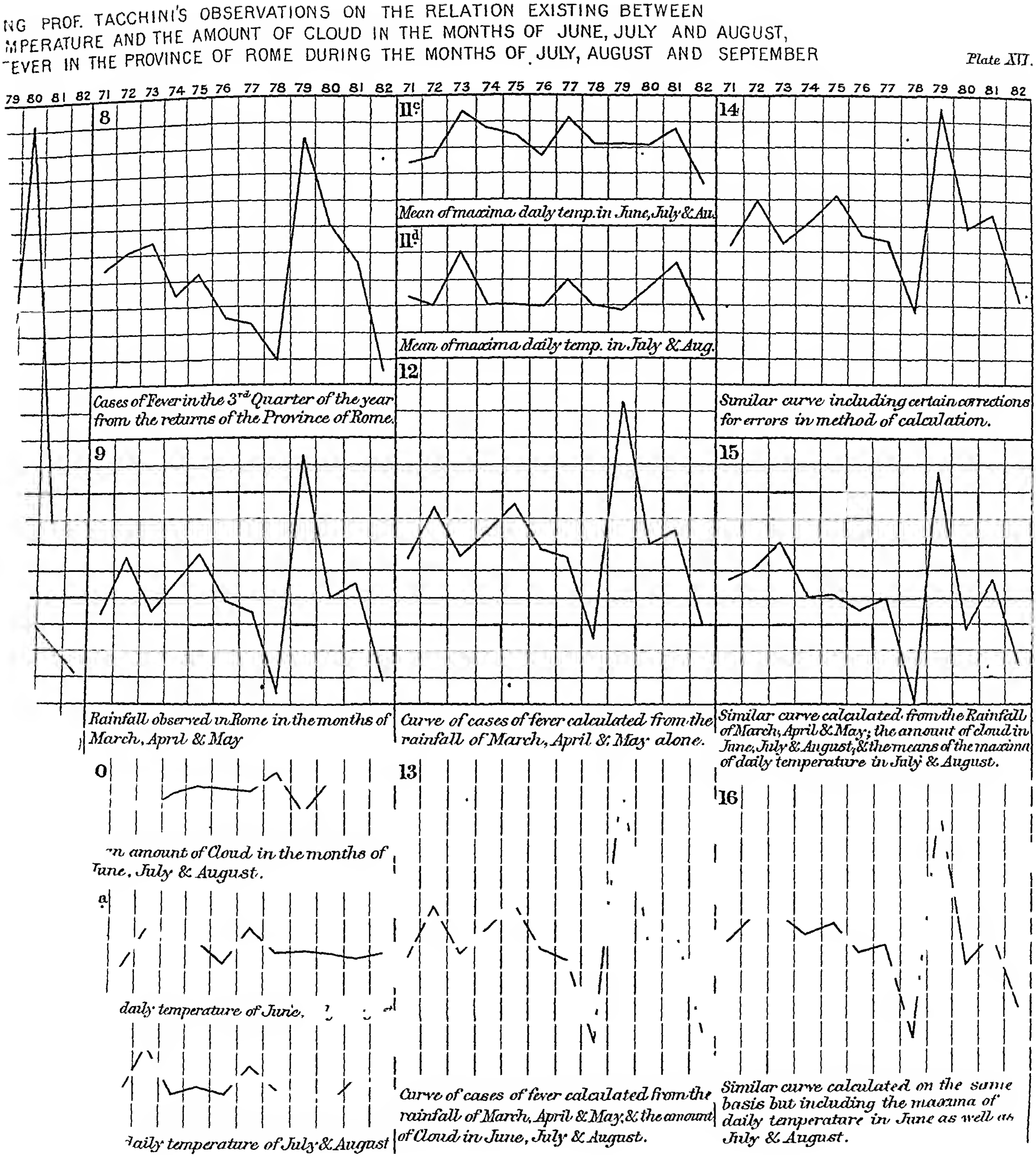
Year.	Percentage of Cases.	Pecentage of Cases, *including* Roman Hospitals.*
1871	6·39	4·65
1872	7·08	7·69
1873	7·35	8·57
1874	5·45	7·76
1875	6·21	5·30
1876	4·57	6·56
1877	4·24	6.03
1878	2·93	6·65
1879	**11·42**	**11·83**
1880	8·25	7·70
1881	6·55	6·85
1882	2·49	6·56

It is a matter of common experience that the number of cases and the intensity of the fever in the province of Rome is greatly influenced by the rainfall in the spring. The following table shows the rainfall during March, April, and May, from 1871 to 1882 :—

Year.	Rain in millimetres during March, April, and May.
1871	185·8
1872	251·3
1873	187·7
1874	225·8
1875	258·7
1876	205·0
1877	191·9
1878	101·8
1879	**369·9**
1880	209·8
1881	227·3
1882	115·7
Average	210·9 millimetres.

The spring rainfall of the year 1879 was, therefore, very greatly above the average; and not only was the spring exceptionally wet, but also the preceding winter. The amount of rain which fell between the 1st of October, 1878, and May 31st, 1879, was 1288 mm. (registered at the observatory of the

* The annual mean of the whole province is calculated by Professor Tacchini at 15·22 per cent. of cases of fever to the whole population.



NG PROF. TACCHINI'S OBSERVATIONS ON THE RELATION EXISTING BETWEEN
MPERATURE AND THE AMOUNT OF CLOUD IN THE MONTHS OF JUNE, JULY AND AUGUST,
EVER IN THE PROVINCE OF ROME DURING THE MONTHS OF JULY, AUGUST AND SEPTEMBER
Plate XII.
79 80 81 82 71 72 73 74 75 76 77 78 79 80 81 82 71 72 73 74 75 76 77 78 79 80 81 82 71 72 73 74 75 76 77 78 79 80 81 82
8
Cases of Fever in the 3rd Quarter of the year from the returns of the Province of Rome.
11c
Mean of maxima daily temp. in June, July & Au.
11d
Mean of maxima daily temp. in July & Aug.
14
Similar curve including certain corrections for errors in method of calculation.
9
Rainfall observed in Rome in the months of March, April & May
12
Curve of cases of fever calculated from the rainfall of March, April & May alone.
15
Similar curve calculated from the Rainfall of March, April & May; the amount of cloud in June, July & August, & the means of the maxima of daily temperature in July & August.
0
n amount of Cloud in the months of June, July & August.
a
daily temperature of June.
daily temperature of July & August
13
Curve of cases of fever calculated from the rainfall of March, April & May, & the amount of Cloud in June, July & August.
16
Similar curve calculated on the same basis but including the maxima of daily temperature in June as well as July & August.

Collegio Romano in Rome), or nearly *double the normal annual rainfall.*

The curves Nos. 8 and 9, Plate XVI., show more clearly than the statistics the close and intimate relation which exists between the spring rains and the amount of fever.

So close is this relationship, that Professor Tacchini has calculated a table of fever cases per cent. of population from the statistics of rainfall, which agrees very closely with the returns of fever actually received (compare curve 12, Plate XVI.), and has evolved the following formula:—

The quotient obtained by dividing the rainfall in millimetres, during the months of March, April, and May, will give the probable percentage of cases of fever in the months of July, August, and September, of the year under consideration: the result is generally slightly in excess of the truth. For example, for the year 1879 the figures are 11·4 per cent. observed, and 12·3 per cent. calculated.

Professor Tacchini has also observed a similar close relation between the cases of fever and the amount of cloud during the months of June, July, and August (see curve 13, Plate XVI.).

The next meteorological factor to be considered is

TEMPERATURE.

'In dealing with temperature observations we must remember that the temperature of the air, as recorded by thermometers, is the result of a number of complex conditions, difficult, if not impossible, of dissociation one from another. The observations are usually made at regular intervals day and night, and these, though controlled by the records of other instruments giving maxima and minima, are so far apart as to give us but a very incomplete idea of the real daily temperature curve.

The only observatory records which we can consider in this connection are these maxima and minima.

The following table shows the mean temperature and the

mean maximal temperature during the months of June, July, and August, of the period of twelve years under consideration:—

Year.	Mean temperature of June, July, and August.	Mean temperature of July and August.	Mean of maxima, June, July, and August.	Mean of maxima, July and August.
1871	22·8	24·4	28·4	30·3
1872	23·1	24·3	28·7	30·0
1873	24·6	26·2	30·4	32·1
1874	24·0	24·3	29·8	30·0
1875	24·0	24·5	29·4	30·0
1876	23·2	24·2	28·7	29·9
1877	24·7	25·4	30·1	31·0
1878	23·7	24·4	29·2	30·0
1879	23·8	24·4	29·2	29·8
1880	23·6	24·0	29·1	30·6
1881	23·3	25·0	29·8	31·7
1882	23·6	24·4	27·7	29·4

There is nothing in these figures which at once attracts attention. When represented graphically, however (Nos. 11*a*, 11*b*, 11*c*, 11*d*, Plate XVI.), the year 1873 shows an absolute maximum, whether we take the mean daily temperature of the months of June, July, and August, or of July and August alone. And it is remarkable that in this year, despite a *decrease* in the spring rainfall, there was a marked increase in the number of cases of fever in the province, whilst, in 1878, with a minimum of rain in spring, and a comparatively low temperature in June, July, and August, there was an absolute minimum of fever.

We come now to the year 1879: with a maximum of rain in spring, and a somewhat low temperature in June, July, and August, we have an absolute maximum of fever. The July of that year was remarkable even in Rome for the exceeding coldness of the nights, whilst the day temperature was the highest recorded in the year. In fact, the mean minimum July temperature for the twelve years under consideration was 18°·75 C., whilst that of July, 1879, was but 16°·83 C., and is the lowest of the whole series (it must be remembered that these observations were all made at the

Collegio Romano, in the heart of the city), whilst on the night of July 12th, 1879, the thermometer fell to 13°·4 C.

These exceedingly low night temperatures were not confined to Rome itself, but were recorded also at Velletri.

The calculation of the percentage of fever cases on the spring rainfall resulted in a mean error of $\pm$ 1·3. Calculated on the rainfall and cloud together this error is reduced to $\pm$ 1; and when the temperature is taken into account, it falls to $\pm$ 0·8.

These figures can have but one meaning; they prove to a demonstration the absolute dependence of the percentage of cases of fever upon meteorological conditions, and, translated into words, they tell us that, when the soil is soaked with water in the spring and beginning of summer, the maximum difference between the maxima and minima of the thermometer during the hot months is excessive, and is accompanied by a corresponding increase in the intensity of the fever in the autumn. Under these conditions, the heat of the sun is employed during the day in evaporating the excess of water from the soil, and, but for the cloudless sky above, the resulting dew might be mistaken for rain, so heavy is it. The part played by the excess of water in the soil in lowering the temperature at night requires no comment; and no one who has ever passed a night in the Roman Campagna, in the months of July or August, will require to be reminded of it. The intolerable heat and dust of the day is succeeded about sunset by a delicious but treacherous coolness, which passes suddenly into a relatively intense cold. The clothing which during the day was regarded as uncomfortably heavy, though barely sufficing to protect the body from the sun, becomes utterly insufficient; extra wraps become necessary, and a blazing camp-fire something more than grateful. Towards daybreak the fall of temperature is often very excessive, and the first signs of dawn are welcome as the precursors of returning warmth. But no sooner is the sun well above the horizon, and the mists have cleared away before it, than the heat becomes oppressive, and the absence of shelter from the sun painfully apparent.

We have said that the usual observatory statistics give but a very poor idea of the *rate* at which these changes of temperature occur. It has been continually asserted that these violent changes of temperature are characteristic of malarious countries. It occurred to the author, therefore, after considerable personal experience of them in the Roman Campagna, and a careful study of localities in which, according to those best qualified to give an opinion on the subject, they prevailed in a marked degree, to submit the whole question to the test of experiment, by continuous observation for many hours, of wet and dry bulb thermometers, suitably placed in pairs, and so to obtain definite and precise information as to their extent and the limits over which they prevailed.

These observations were conducted in the summer of 1885, in which the malaria in the Roman Campagna reached a degree of intensity such as it has but rarely approached in the present century. The outbreak was foreseen and predicted, for the conditions were precisely those of the year 1879. The autumn of 1884 was exceptionally wet, and all through the winter the rain descended in almost unceasing torrents. It can hardly be said that there was any true spring, and when the weather at last broke the summer had set in, and the heat which accompanied it was almost as exceptional as the preceding rains. The lower parts of Rome were flooded, not once, but several times during the winter, and it was feared that the disasters of 1870 were about to be repeated. The Campagna, as seen from the Alban Hills, was studded with small lakes, the cross roads became almost impassable, agricultural operations were stopped, and on all sides nothing was heard but complaints of the damage done by water. Under these circumstances, and with the experience of the year 1879 as a guide to the results to be expected, the series of observations detailed in the next chapter were undertaken, in the hope that they might throw some light on the precise relations of malaria to meteorological phenomena, and possibly help to explain the extremely local variations of intensity of the disease which beyond all doubt exist.

CHAPTER XIII.

LOCAL METEOROLOGY IN RELATION TO MALARIA.

THE evidence which has been thus far adduced proves beyond all reasonable doubt the intimate relation which exists between malaria and certain meteorological phenomena, notably rainfall and temperature. We have further seen that apparently trivial local conditions, such as small variations of altitude, the local distribution of subsoil water, and the conformation of the soil, produce effects on the distribution and intensity of the disease so remarkable as to render the careful study of very small areas a necessity, in order to elucidate as far as possible the precise nature of these local peculiarities and their influence upon the production of malaria.

We have already had considerable evidence to show that the form of the daily temperature curve, on a given area, represents the net result of the operation of these complex factors; and their general relation to the disease being now beyond all doubt, it is our duty to pursue them in detail, in order to discover whether or no the relationship still manifests itself in the curiously local variations in its distribution which practical experience has shown to exist.

It may appear to some, and not unnaturally, that a disease so widely spread, and, as must be admitted, having the same, or a similar, cause, wheresoever it manifests itself, cannot be the subject of such great variations of intensity over such exceedingly limited areas, and that these variations are apparent rather than real, and due to the irregular and scanty distribution of the population from which the information is

derived. The author is bound to confess that he was himself very incredulous at the outset; but after long and careful inquiry, and the minute examination of a large number of localities in which these peculiar variations were said to exist, he was fully convinced of their reality, and, as a natural consequence, that the study in such places of the local meteorological phenomena would either reveal the cause or throw much light upon the ætiology of the disease.

The whole energies of modern investigators of the subject have been directed to the discovery of some organism which is assumed to be the cause of intermittent fever, and but little attention has been paid to the conditions under which it manifests itself. In the author's opinion, the reverse of this process is the only logical one—namely, to study the conditions; to narrow the inquiry from a continent to an individual country, from a country to a province, and from a province to a square kilometre, or even less, of soil; and having done this, to determine accurately how far the general conditions apply to the small area under consideration; and then, by comparison of the results of the study of several such areas, to discover a constant which may be connected with the disease in such a way that it must be regarded either as the cause itself, or as governing the operation of that cause so completely, that, from the practical and sanitary point of view, it may be considered as a something the removal of which will cause the disease to cease.

This has been the author's plan in the conduct of this inquiry, and though it has had for one of its results the accumulation of a great mass of what may appear to some wearisome and uninteresting details, he feels no hesitation in presenting them as absolutely necessary to a right understanding of the subject, and as fulfilling at least one important function—namely, that of clearing the ground for future investigators.

The plan of the observations about to be detailed was, theoretically, exceedingly simple. It consisted in the placing of a number of pairs of wet and dry bulb thermometers upon a malarious site, in such a way as to comprise the local varia-

tions of intensity said to exist upon it, and to take careful readings of these instruments as frequently as possible during a period of at least twenty-four hours.

Simple though the plan of such observations appear to be at first sight, difficulties presented themselves on all sides as soon as an attempt was made to put it into execution.

The difficulties were such as can hardly be said to exist in England: the country is safe; communication is practically perfect; instruments of all kinds can be obtained at short notice; and willing help is to be had almost for the asking.

In the Roman Campagna the conditions are entirely different: the most suitable districts for such observations are uninhabited in summer or practically so; further, a stranger in these lonely places, in the midst of ignorant and superstitious people such as are the scanty inhabitants, is more or less under the necessity of providing for his personal safety, and is continually under the restraint produced by the obligation of guarding against ignorant interference and molestation; communication is exceedingly difficult; the barest necessities of life have to be carried to the spot, and even menial assistance is not to be obtained without great difficulty.*

The loss of, or damage to, instruments and apparatus cannot be repaired without great loss of time, and the conditions generally are such as to necessitate the observer rendering himself as independent as possible of all extraneous help whatever, and to make provision against all possible contingencies.

Scientific observations under these circumstances are rendered difficult and unpleasant, and the localities chosen for the series now to be described were largely determined by considerations which prevented their being carried out continuously, and in places in which the fever was more intense and the local variations more marked.

The instruments used were good chemical thermometers,

* On one occasion the offer of ten times the usual daily rate of pay, with an unlimited supply of food, wine, and tobacco, failed to secure the services of a man to assist the author in some observations he intended making about half-way between Rome and Ardea, so great is the dread of the fever.

graduated on the glass, and reading to tenths of a degree Centigrade. They were mounted in pairs, with the bulbs ten centimetres apart, in shallow wooden boxes, just deep enough to protect them from injury in transit. In the arrangement of the instruments, method of exposure and of taking the observations, the directions and precautions given by Mohn * were followed as closely as circumstances would permit.

The carriage of a number of louvred frames was under the circumstances quite impossible; it was therefore necessary to devise some other method of protecting the thermometers from the direct action of the sun's rays. This was effected by means of double canvas tents, so arranged as to give perfect ventilation, and placed at some distance above the thermometers with large hanging flaps to break the wind. The instruments were invariably placed so as never to be in a direct line with the sun, and in all cases in which such action was to be feared a canvas screen was arranged so as to throw a broad shadow over the instruments and their coverings.

In order to support the instruments in convenient places on open ground, and at the same time to enable the exact height of the bulbs of the thermometers above the soil to be arranged with facility, surveying staves, jointed together and provided with movable rings for the attachments of the instruments, were used. These poles, kept in position by guy-ropes, answered their purpose admirably, the ropes serving as the support for the canvas tent, and flaps, which were used in place of the usual louvred frames; dead trees, telegraph poles, and fence posts were made to serve the same purpose; a few screw hooks and tent pegs, and a number of suitably cut pieces of canvas, enabling a temporary shelter for the instruments to be constructed in a few minutes. Duplicate tents had to be carried in order to provide against the heavy dews, which by soaking the canvas, created, as was found by special experiment, an atmosphere artificially saturated with moisture, which vitiated the readings of the wet bulb instrument. As a rule, after nightfall, the covers were

* *Elementi di Meteorologia*, tradotto da D. Ragona (Torino: Loescher, 1884).

removed entirely, and used at some little distance as a protection against the direct action of the wind. Large pieces of white calico about half a metre square were used on very dark nights, to enable the position of the instruments to be recognized; but this plan had to be discontinued, as it was found to attract insects, and on more than one occasion a belated traveller whose absence was more desirable than his company. On one occasion, at Tre Fontane, the distance across the open Campagna between one instrument and the next being nearly 1½ kilometres, the quickest method of finding the distant point in the darkness was by compass.

The general direction given in works on meteorology, that thermometers should be placed at a certain height *over grass*, was, of necessity, disregarded, and indeed could rarely have been carried out, in consequence of the great variations in the nature of the soil and its cultivation. As the object of these observations was to determine the form of the daily temperature curve in different localities, under the then prevailing conditions, the instruments were placed in such positions as, after careful consideration, appeared to be best suited for observing the peculiar conditions said to prevail in the particular locality under investigation, and the results must be understood in this sense.

The readings of the thermometers as given in the tables were all taken by the author personally, as no skilled assistance was obtainable. It would have been very desirable to have had one observer to each instrument, so that the readings might have been simultaneous; but, this being impossible, the author had to be content with such observations as could be made by making the round of the instruments as frequently as possible night and day. In the cases in which a number of instruments were employed, and the distance between them was considerable, the physical exertion involved was very great, and the time required to make one round of visits such that very frequent observations became impossible. It is perhaps to be regretted that in these cases maximum and minimum thermometers were not used, and as a matter of fact an attempt was made, but it was rendered abortive by

the apparent impossibility of transporting the instruments without shaking them to such an extent that on their arrival they were found to be useless.

The absolute accuracy of each reading is not contended for, but every possible care was taken to avoid serious error, and it is believed that the results, as a whole, faithfully represent the diurnal variations of temperature and atmospheric moisture in the localities, and at the time at which the observations were made.

LOCALITIES IN WHICH THE EXPERIMENTS WERE MADE.

These were as follows :—

1. The immediate neighbourhood of the monastery of San Paolo fuori le Mura, on the Via Ostiense, two kilometres from the gate of the same name.
2. The Tenuta of Tre Fontane, on the Via Laurentina.
3. The Vigna Deserti near Acqua Bollicante, on the Via Casilina.
4. The Angle of the Isola Sacra (Capo due Rami), between the Tiber and Trajan's Canal.

As before stated, the choice of these localities was governed by a number of circumstances not altogether within the author's control. It was his original intention to have made the observations in districts much further from Rome, such as the Pontine region, the neighbourhood of Ardea, Campo Morto, and some places to the north of the Tiber; but the difficulty of transporting the necessary apparatus, of procuring even menial assistance, and the absence of any inhabited dwellings, to which must be added the possibility of being incapacitated by the disease in remote and lonely places, far away from help of any sort, rendered it necessary to confine the observations to localities within more or less easy reach of Rome.

Though perhaps not the most unhealthy places in the Campagna, they have the advantage of being so far inhabited

that their local peculiarities are well known, and it was thus possible to obtain detailed information of great value in determining the position of the instruments, and some history of the variations in the intensity of the disease in each place, which to a considerable extent compensated any disadvantages they might possess in other respects.

SERIES I.

SAN PAOLO FUORI LE MURA JULY 21 AND 22, 1885.

THE neighbourhood of the famous Basilica has always had a most evil reputation for unhealthiness. Attached to it is a large monastery, from which all the monks are withdrawn in May to the house belonging to the order in Rome, and they do not return until November. During the summer a priest and sacristan are left in charge, but these are changed every forty-eight hours. The end of the monastery opposite the *osteria* (see map) has been converted into a barrack for the Carabinieri, of whom six are lodged there. Until the year 1884 it was the custom to withdraw them in the summer months, but in view of the apparently increased healthiness of the Campagna in the preceding four or five years, it was decided to allow them to remain during the summer of 1885. The result, considering the character of the preceding winter and spring, might possibly have been foreseen ; the *brigadiere*, who was often away in Rome on business, was the only one who escaped fever, and when it was too late the men were withdrawn. A gardener and assistant gardener were the only other persons employed about the place, but they lived in Rome, and returned every evening to sleep there. At the *osteria* opposite lived the host and his wife, two daughters, and a son. They always slept in the house at the end of the footpath leading from the *osteria* up the hill, some twenty-two metres above the level of the road, and built on the hard tufo of which this hill is composed.

All had fever, but only slightly. It may be mentioned that

they were people comparatively well to do, well fed and clothed, and though working very hard, were not exposed to the same extent as the ordinary Campagna labourers. The *osteria* at the angle of the Via delle Sette Chiese, was locked up at sunset, and the people in charge went away to Rome to sleep. A man engaged in some work about the house slept there for eight or nine nights in August, and was attacked by fever in a somewhat grave form. The *osteria* between the Basilica and the river is also shut up at sunset, and the occupiers go away to Rome to sleep: the same applies to the *osteria* at the Ponticello. At the *forno*, or baker's shop, on the road towards Rome, those in charge take it in turn to sleep there one night in every four, and in spite of this precaution one of them fell seriously ill of a quotidian ague, which clung to him for over five months. At the little house on the river bank, near the four poplar trees, lived, in a state of wretchedness indescribable, a family of Ciociari from Scarpa, a miserable little village in the Sabines, between Tivoli and Subiaco. They were eight in all—father, mother, and six children, ranging from sixteen to three years of age, the mother far advanced in pregnancy. The place in which they lived cannot be called a house; it was a mere shed with barely standing-room for the inhabitants. A very slight flood in the Tiber sufficed to put a foot of water into this hovel, and leave the usual two or three inches of mud on the ground inside (there was no flooring). The father earned about seven or eight francs a week by doing irregular work for the monks in summer, his real occupation being to watch a few tons of *pozzolana* which stood at his front door, or rather the hole in the wall which served as such, and for which work (*sic*) he was not paid until October, inasmuch as the *pozzolana* was the subject of litigation, and had no owner. Meat these wretched folks never tasted; bread and green stuff from the monastery garden was their staple food, and they all fell ill of fever in the same week; the father and second daughter were attacked but slightly, and soon recovered, at all events approximately; the mother and the youngest child took the disease in a very grave sub-continuous form, and for some days their lives were in peril. Out of the wretched

means at their disposal they had to purchase quinine ; where it was obtained the author was unable to discover, but often two francs were spent in this way. The author obtained possession of a packet on one occasion, and on a rough examination had no difficulty in pronouncing eighty per cent. of it not to be quinine at all, but starch and pounded Epsom salts.

Although there prevail in all malarious countries a number of superstitions regarding the effects of food upon a patient suffering from the disease, there appears to be a general consensus of opinion that those who are well fed have comparatively little to fear—very much less than the half-starved and destitute. This family appeared to the author to present an excellent opportunity for studying the relative curative effects of good food and quinine respectively. Accordingly, to the three elder children a ten-grain dose of Howard's quinine was administered, and to the youngest child a smaller dose ;. the elder children, who were too ill to eat, had a small quantity of red wine in addition to the quinine ; the rest of the family had a good meal of meat, bread, salad, and wine. The result of this treatment was most satisfactory. On the following day every member of the family, excepting the youngest child, was free from fever, and even it was free for the greater part of the day. It would appear, therefore, from this example that a sufficiency of good food is capable of bringing about the same result as quinine—at all events, such was the result in this case. Nor is this the only example in point which has come within the writer's experience. The remedy appears to act with the greatest certainty on those patients who are suffering from prolonged under-feeding, and upon these its effect is sometimes almost magical.

There is a very prevalent notion in the Campagna that to eat during an attack of fever is dangerous, and likely to increase the severity of the disease. Undoubtedly, to load the stomach with improper or with an excessive quantity of food, when the fever is severe and the patient weak, would be likely to do more harm than good, and probably result in its immediate rejection ; but the author is strongly of opinion, both from personal experience and as the result of observation

of others, that in those cases in which the patient can take and retain food, especially, as before said, in those who, like but too many of the Campagna peasantry, are suffering from prolonged under-feeding, a few ounces of well-cooked fresh meat, and a liberal allowance of good red wine, will have an effect, equal, if not superior, to a large dose of quinine, without any of the mischievous results which are liable to follow the administration of the drug *during* the fever. This is especially the case in those irregular sub-continuous forms which are so frequent in a poorly fed population: it appears to raise the power of resistance, and justifies the setting aside of some of the rules of treatment. Sufficient has been said to show that the neighbourhood of San Paolo is fever-stricken in a very serious degree. The nature and conformation of the soil must now claim our attention.

The land between the Via Ostiense and the Tiber is practically level, and is formed from the alluvium of the river. The most curious and striking feature of the area under consideration is the mass of hard tufaceous rock which rises abruptly at the angle of the Via delle Sette Chiese. The top of this hill is planted with a few olive trees, and the slopes with vines, until we reach a line running due east and west through the entrance to the *osteria* (see map, Plate XVII.), where the slope suddenly becomes very gradual, and the character of the soil alters entirely. On the top of the hill the soil is tolerably deep, and very fine and light, consisting of the *débris* of rock below, it possesses sufficient adherence to cake together at the surface after rain and subsequent sun; but the layer thus formed soon breaks down again, and walking amongst the vines is in some places a labour, on account of the ease with which one sinks into the soil. It absorbs water greedily up to a certain point, the excess running off southwards to the level very rapidly, upon the surface of the rock below. The more level piece before mentioned is of an entirely different character. First, instead of being dark brown, it is more of an iron-grey in colour, exceedingly clayey and tenacious, adhering to the boots in such a way as to make walking over it very unpleasant, and whereas on the hill there is no difficulty in

running a walking-stick up to the hilt in the soil, here it requires great force to persuade it to penetrate even a few inches. This lower land is always wet, even in August, an inch or two below the surface, and is intersected by numerous drains, which always contain water, and abound in frogs and toads. As indicated on the map, there is a small cane brake near the edge of the *marrana*, or ditch, and here there is always a bog; the land is planted with vines which yield well, but the chief crop is tomatoes. The proprietor stated that when he first took the land, in the year 1873, it was a swamp, so foul and stinking that, as he put it, "the toads would not live in it." With the exception of the part covered by vineyards, the whole of the low land south of the monastery is boggy, and grows a poor sort of grass. (By boggy is to be understood, of such a nature that a slight fall of rain causes the water to stand in pools in the grass, and even in summer a walking-stick will readily demonstrate the presence of water a very short distance below the surface.)

The corner near the *osteria* del Ponticello has been excavated for an inferior kind of clay which it contains; and at the time these observations were made, was covered by large muddy pools full of green slime, and having a very foul odour in hot weather. The higher land is all similar in structure to that near Tre Fontane, already described (page 40), and the water falling on it nearly all finds its way to the level swampy land just mentioned The Basilica itself affords a very good criterion of the dampness of the locality, though in this case filtration from the Tiber probably plays an important part. The magnificent marbles which cover the walls and floor of the Basilica are often quite wet, even in July; and the effect upon the polished stone of this excessive moisture is such as to require constant attention to prevent serious damage. If the water of the Tiber rises beyond a certain level, the water filters through the foundations and makes its appearance in the lower part of the building.

The facts above stated will suffice to give some idea of the character of the neighbourhood of the Basilica, and, with the map and sections subjoined (Plate XVII.), will serve to render

the descriptions of the observations and position of the instruments fairly intelligible.

The observations made in the neighbourhood of San Paolo were as follows:—

1. From 12.50 P.M. on Tuesday, July 21st, to 12 noon on Wednesday, July 22nd.

2. From 6.15 P.M. on Friday, July 24th, to 5.30 P.M. on Saturday, July 25th.

3. From 5.50 P.M. on Tuesday, July 28th, to 6 P.M. on Wednesday, July 29th.

4. From 5.30 P.M. on Monday, August 3rd, to 3 P.M. on Tuesday, August 4th.

5. From 6 P.M. on Thursday, August 6th, to 6 P.M. on Friday, August 7th.

As has been already mentioned, the choice of localities in which to carry out these observations was rendered difficult by a variety of circumstances; and many places selected as suitable, after careful consideration had to be abandoned. One of these was the site of the ancient Bovillæ, on the Via Appia Antica, about ten miles from Rome. In the early days of the Empire, Bovillæ[1] was a fashionable suburb; and its early history carries us back to the time of the Tarquins and the Latin League, when the place was famous for its rich pasturage, which, according to some authorities, is the origin of its name.[2] Some small remains of a theatre and other buildings are all that now mark the site, and the locality is exceedingly unhealthy. About a mile further along the Via Appia Antica, at the point where it is joined by the Via Appia Nuova, and from which the road ascends to the town of Albano, stands a small *osteria*, known as "Le Frattochie." Some three weeks before this first experiment was made, the author visited this place, in the hope of being able to make arrangements for carrying out a series of observations in the

[1] "Quippe suburbanæ parva minus urbe Bovillæ."—Propertius, *Eleg.*, lib. iv. 1-33.

[2] Florus, lib. i cap. xi.

immediate neighbourhood. At the time of this visit all the occupants of this *osteria* were suffering from ague, the result, in their opinion, of having delayed their return to Marino, a small town in the Alban Hills, in which they lived during the summer and autumn. The hostess presented a typical case of chronic malarial infection; her spleen was greatly enlarged, tender and painful, causing considerable suffering by interfering with respiration and digestion, owing to pressure on the diaphragm and stomach; the fever was sub-continuous, and accompanied by repeated attacks of the characteristic deep-seated rheumatic pains in the limbs, usually declared by the patient to be in the bones; her husband had but recently recovered from an acute attack of fever; and a child had been sent up to Marino a few days previously, suffering from the same disease.

Not far from this place some *pecorari*, or shepherds, who for some reason or another had delayed their departure to the mountains, had constructed small platforms of stakes and wattles, and a rough cover of the same material just long enough to contain and shelter one man. These platforms were about seventy-six centimetres (two feet six inches) above the soil, and as there was an abundance of dry twigs and brushwood about, it was apparent that there was some reason for the construction of these rude couches. When questioned, it was explained that, though a colder bed, it was safer than lying on straw simply spread upon the ground. It was perhaps hardly reasonable to expect ignorant men, such as these *pecorari* are, to give any grounds for such a procedure, seeing that the construction of these frames is probably a custom handed down from father to son, and blindly followed; but these particular shepherds insisted, when further questioned, that the free ventilation under their beds was of great value as a preventive against fever. Whether this was actually the case, there was no means of forming an opinion; but it appeared to the author that so much trouble would not be taken unless some real or imagined benefit, or greatly increased comfort, were derived from it, and accordingly, this first series of observations was undertaken in order to examine

the variations of temperature and atmospheric moisture at comparatively small heights above the soil, in the hope that some explanation might be found for this custom.

Two instruments were used, placed vertically over one another on the apparatus already described (page 154). The bulbs of the upper pair were placed at a height of 2·30 metres (7·5 feet), those of the lower pair at 1·10 metres (3·3 feet) above the earth. The standard was planted at about the intersection of the diagonals of the garden (marked Orto on the map, Plate XVII.) of the monastery, upon soil growing two-year-old vines. The garden wall is about five metres (fifteen feet) in height, the wall of the monastery about twenty metres (sixty-five feet); there were no trees of any size in the garden; the soil was dry and hard on the surface, but always damp at the depth of half a metre, even after long drought. Observations were made as nearly as possible every half-hour from 12.50 P.M. on July 21st, to noon on July 22nd. The results are given in the following tables, in which

D.B. signifies readings of the dry-bulb thermometer.

W.B. signifies readings of the wet-bulb thermometer.

U.R. relative humidity, *i.e.* the percentage of aqueous vapour contained in the air as compared with saturation at the given temperature.

Tension, signifies tension of aqueous vapour in millimetres and decimal parts.

All thermometer readings are given in degrees Centigrade.

The tension of aqueous vapour and the relative humidity have been calculated from tables published for the use of the various meteorological stations by the Italian Government.*

In order to render the significance of the figures of the above tables more apparent, it will be convenient to condense and summarize them, and to compare them with similar observations made at an English station as far as possible presenting similar local conditions. The general results have therefore been set out in a second table (Table B.), side by side with the records obtained at the Royal Observatory at Kew,

* *Tavole ad uso della Meteorologia pubblicate per la Direzione di Statistica del Ministero d'Agricoltura, Industria, e Commercio.* Pavia, 1867.

TABLE A.

San Paolo, Tuesday, July 21, *and Wednesday, July* 22, 1885.

UPPER PAIR (NO. 1). PLATE XVIII.

Time.	D.B.	W.B.	U.R.	Tension.	Remarks.
P.M.					
12.50	34·5	28·0	59	24·05	Sky clear; slight breeze.
1.20	33·6	27·5	61	23·50	
2.0	33·1	27·0	60	27·71	
2.30	33·8	27·0	57	22·28	
3.0	33·0	27·0	61	22·77	
3.30	34·0	27·0	56	21·15	
4.0	33·0	27·0	61	22·77	
4.30	33·5	26·5	55	20·79	
5.0	33·5	26·5	55	20·79	
5.30	34·0	26·8	55	21·72	
6.0	32·0	27·0	66	23·40	Wind quite ceased.
6.30	31·0	26·0	65	21·88	
7.0	29·0	25·0	71	21·07	Sky perfectly cloudless.
7.30	27·0	23·6	74	19·57	Began to feel chilly.
8.0	25·5	23·0	80	19·35	A few clouds.
8.30	25·0	23·0	83	19·65	Began to feel cold.
9.0	25·0	23·0	83	19·65	
9.30	23·5	22·0	87	18·73	
10.0	23·0	22·0	91	19·04	
10.30	22·0	21·0	91	17·88	
11.0	22·0	21·0	91	17·88	
11.30	22·0	20·5	87	17·02	Very cold.
12.0	20·8	20·0	93	16·90	
A.M.					
12.30	20·5	19·5	91	16·16	
1.0	20·2	19·0	89	15·61	
1.30	20·0	18·8	89	15·41	
2.0	20·0	18·8	89	15·41	
2.30	19·8	18·5	88	15·06	
3.0	19·5	18·0	86	14·44	No mist.
3.30	19·0	17·8	88	14·43	First signs of dawn.
4.0	18·2	17·2	90	14·00	Dawn; very cold.
4.30	18·0	17·0	90	13·81	No mist.
5.0	17·5	17·0	95	14·11	Minimum temperature.
5.30	18·0	17·0	90	13·81	
6.0	19·0	18·0	90	14·75	
6.30	22·0	20·8	89	17·54	
7.0	25·0	23·3	86	20·22	
7.30	26·6	24·0	80	20·58	
8.0	28·0	25·0	77	21·69	Slight breeze.
8.30	30·0	25·8	70	22·09	
9.0	32·0	27·0	66	23·40	
9.30	33·5	27·4	61	23·34	
10.0	33·0	28·5	70	26·13	
10.30	33·8	29·0	68	26·79	
11.30	36·5	28·4	56	23·68	Maximum temperature.
12.0	35·5	29·5	62	26·40	

TABLE A.

San Paolo, Tuesday, July 21, and Wednesday, July 22, 1885.

LOWER PAIR (NO. 2). PLATE XVIII.

Time.	D.B.	W.B.	U.R.	Tension.	Remarks.
P.M.					
12.50	32.5	26.2	59	21.37	Sky clear; slight breeze.
1.20	32.8	26.3	58	21.40	
2.0	32.6	25.8	56	20.48	
2.30	32.4	25.4	55	19.78	
3.0	32.4	25.6	56	20.20	
3.30	32.4	25.6	56	20.20	
4.0	32.0	25.4	57	20.02	
4.30	31.4	25.2	59	19.99	
5.0	31.2	25.4	61	20.52	
5.30	31.0	25.2	61	20.24	
6.0	30.0	24.6	62	19.66	Wind quite ceased.
6.30	28.6	24.4	69	20.13	
7.0	27.0	23.6	74	19.57	Sky perfectly cloudless.
7.30	25.6	23.2	81	19.66	Began to feel chilly.
8.0	25.2	23.4	85	20.29	A few clouds.
8.30	25.0	23.4	87	20.42	Began to feel cold.
9.0	24.4	23.0	88	20.02	
9.30	23.4	22.6	93	19.90	
10.0	22.8	22.2	95	19.54	
10.30	22.0	21.5	96	18.77	
11.0	22.4	21.3	90	18.17	
11.30	21.4	20.8	95	17.91	Very cold.
12.0	20.2	19.8	96	16.93	
A.M.					
12.30	20.8	20.0	93	16.90	
1.0	19.8	19.2	94	16.19	
1.30	20.6	19.2	87	15.70	
2.0	20.6	19.0	85	15.37	
2.30	19.2	18.4	92	15.26	
3.0	19.6	18.4	89	15.02	No mist.
3.30	18.6	18.0	94	14.99	First signs of dawn.
4.0	18.7	17.8	91	14.62	Dawn; very cold.
4.30	17.8	17.2	94	14.34	No mist.
5.0	17.2	16.8	96	14.00	Minimum temperature.
5.30	18.0	17.4	94	14.42	
6.0	19.0	18.2	92	15.07	
6.30	23.4	21.2	81	17.37	
7.0	26.4	23.6	78	19.93	
7.30	28.0	24.0	70	19.71	
8.0	29.8	24.6	63	19.78	Slight breeze.
8.30	31.4	25.6	61	20.81	
9.0	32.4	26.4	60	21.86	
9.30	33.8	27.2	58	22.71	
10.0	33.4	27.3	60	23.18	
10.30	34.6	28.4	61	24.90	
11.30	34.8	27.2	54	22.09	
12.0	35.4	28.0	55	23.49	Maximum temperature.

for which purpose the hourly readings for the year 1885 have been utilized.

Kew is in many respects very similarly situated to San Paolo. It is an inland station in a river valley—the valley of the Thames—at an altitude of 10·36 metres (thirty-four feet) above sea-level. The garden of the Basilica is about twelve metres above the datum line. The distance from the sea in each case is sufficient to constitute both places inland stations in the sense understood by meteorologists, so that in respect of these three factors—altitude, distance from the sea, and position in a river valley—the two places are fairly comparable. Difference of latitude must of course be considered in making the comparison, the difference between the mean annual isothermal lines which pass through London and Rome respectively being a little more than 5° C. (10° F.).

The figures in Table B. are divided into two groups, in order to facilitate reference—namely, those relating to temperature and those relating to the aqueous vapour present in the atmosphere, and have been obtained as follows :—

The mean temperature, mean relative humidity, and mean tension of aqueous vapour, have been obtained by adding together the whole of the observations and dividing by their number.

The mean hourly variation of temperature and tension of aqueous vapour has been obtained by subtracting the figures of each observation from those of the next, and dividing the sum of the differences so obtained by the number of hours over which the observations extended. This method is simple, and, though not strictly accurate, gives an approximation sufficient for our purpose.

The fall of temperature per hour to the minimum is calculated from the highest reading before this minimum, and the rise of temperature per hour to the maximum is calculated for the period between the absolute minimum temperature, and the highest reading obtained between this minimum and the close of the observations. This, in several cases, was not the absolute maximum observed.

The whole of the hourly observations made at Kew have

been used for the period over which the series under consideration extended, and no attempt has been made to select those hours which most nearly coincided with the time of observation in Rome.

It will conduce to clearness if, as far as possible, we examine the results of each series in the following order: temperature; aqueous vapour; comparison of both with the observations made at Kew, in the same period.

TABLE B.

July 21 *and* 22, 1885.

	Kew.	San Paolo.	
		1.	2.
Mean temperature	17·9	26·5	26·2
Maximum temperature	22·5	36·5	35·4
Minimum temperature	15·1	17·5	17·2
Excursion of thermometer	7·4	19·0	18·2
Mean hourly variation of temperature	0·68	1·8	1·8
Fall of temperature per hour to minimum	0·62	1·06	1·0
Rise of temperature per hour to maximum	0·67	2·92	2·6
Mean relative humidity	70	75	73
Mean tension of aqueous vapour	10·77	19·3	18·5
Maximum tension of aqueous vapour	12·50	27·71	24·90
Minimum tension of aqueous vapour	9·35	13·81	14·00
Range of tension of aqueous vapour	3·15	13·90	10·90
Mean hourly variation of tension	0·38	2·21	1·18

Considering these results in the order named, we find that the mean temperature recorded by the upper instrument was 0°·3 C higher than that recorded by the lower one. The difference between the two minima is also 0°·3 C., whilst between the maxima it is 1°·1 C., so that we may conclude from these observations that the temperature of the air increases slightly as we rise above the surface of the soil. The excursion of the thermometer was in both cases very great, 0°·8 C. more in the upper instrument than in the lower, the mean of the two being 18°·6 C. (33°·5 F.).

The mean hourly variation of temperature was the same for both instruments, and it is only when we consider the form of the curves obtained from the two sets of records that we

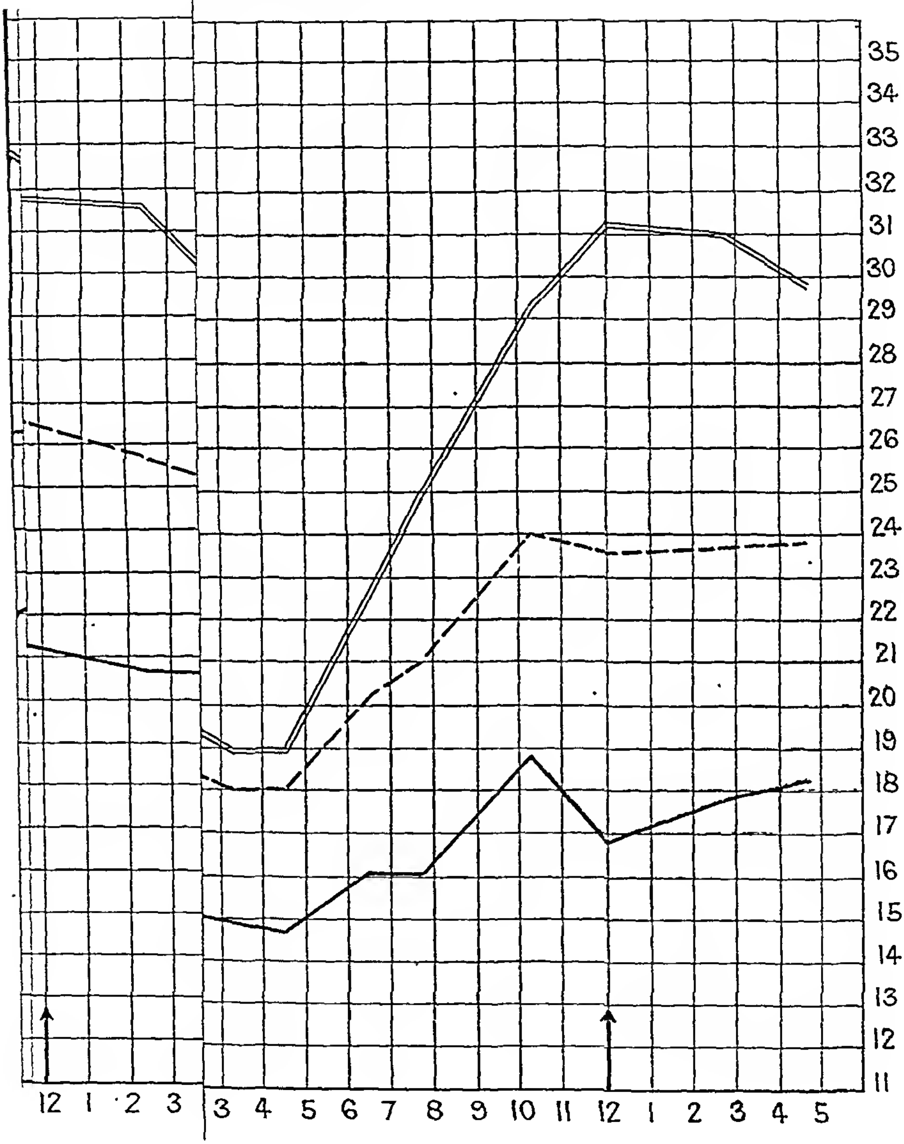
discover any important difference (Figs. 1 and 2, Plate XVIII.). Both curves present a very characteristic feature, viz. a very rapid rise to the maximum as contrasted with the fall to the minimum. The rate of fall to the minimum is practically the same in both cases; but there is a difference in the rate of rise to the maximum of 0°·32 C. (rather more than half a degree Fahrenheit) in favour of the upper instrument, the hourly rates of fall and rise being in the ratio of 1 : 2·7 and 1 : 2·6 in the upper and lower instruments respectively, or, speaking roughly, the hourly rate of rise of temperature approaches *three times* the hourly rate of fall.

Aqueous Vapour.—The mean tension of aqueous vapour and the mean relative humidity recorded by the upper instrument is in both cases higher than that recorded by the lower, as is also the range and mean hourly variation of tension. From these results we may conclude that at a height of 2·30 metres ($7\frac{1}{2}$ feet) above the soil the mean temperature is higher, the total excursion of the thermometer, and the mean hourly variation of temperature, are slightly greater than at a height of 1·10 metres (3·6 feet), and the same applies to the aqueous vapour present in the air.

Comparing the observations made at Kew in the same period, we find that the mean temperature was 17°·9 C., or nearly 8°·5 C. (15°·3 F.) lower than at San Paolo. Comparing the maxima, we find the temperature at Kew 13°·4 C. (24°·1 F.) lower than at San Paolo; the minimum was 2°·25 C. (4°·05 F.) lower, and the excursion of the thermometer only 7°·4 C. (13°·3 F.) as against 18°·6 C. (33°·5 F.) at San Paolo. The mean relative humidity at Kew, though little less than at San Paolo, was far more constant, the mean tension of aqueous vapour at the former place being but little more than *half* that at San Paolo, whilst the range of tension was exactly *one-fourth*. The mean hourly variation of temperature and atmospheric moisture at Kew presents the same contrast; the former showing rather more than *one-third* and the latter *one-sixth* of the rate of change occurring at San Paolo.

The most striking difference between the two places is shown in the rate of fall per hour to the minimum, and the

1. 1·30 metre above soil



rate of rise to the maximum. At Kew they are practically *equal*, whilst at San Paolo there is a mean difference between the two rates of $1^{\circ}\cdot7$ C. ($3^{\circ}\cdot06$ F.).

The points of difference between Kew and San Paolo, as shown by these observations, may be summarized in a very few words.

At San Paolo the range of temperature is excessive, and the hourly variations very great, especially after the minimum is passed. At Kew, the range is moderate, and the hourly variations very regular throughout the whole twenty-four hours.

At San Paolo the amount of aqueous vapour present in the air is great, and subject to excessive and irregular variations. At Kew, though relatively to the temperature the tension of aqueous vapour differs but little from that at San Paolo, the variations are small and regular. The bearing of these facts will be dealt with in the summary of the whole of the observations.

SERIES II.

SAN PAOLO FUORI LE MURA, JULY 24 AND 25, 1885

HAVING from the previous observations obtained a general idea of the form of the temperature curve and the effect upon it of small differences of altitude above the soil, the points which next appeared to demand investigation were, the effect of difference of soil in modifying the form of the curve and of difference of altitude above sea-level.

The vineyard opposite the Basilica, which extends from the corner of the Via delle Sette Chiese to the *marrana*, where a road turns off to the left from the Via Ostiense to some vineyards belonging to the monastery (see map, Plate XVII.), was chosen for these observations, as presenting within a very small compass all the conditions required.

The average height of the ground near the *marrana* is 12 metres (39 feet) above sea-level, whilst the top of the hill, already described (page 161), is 42 metres (137½ feet) above the sea; that is to say, there is a difference of 30 metres (98½ feet) between the level of the road and the top of the hill.

The thermometers were placed as follows:—

Nos. 1, 2, and 3, one above the other, in the same vertical line, on the low land, about 20 metres (65 feet) from the *marrana* and the same distance from the field drains. This low land was, at the time the observations were made, planted with tomatoes.

No. 1 (a pair of common thermometers) was placed with the bulbs 10 cm. (4 inches) above the soil; No. 2, 1 10 metres

(3·6 feet), and No. 3, 2·3 metres ($7\frac{1}{2}$ feet) above the soil. The *marrana* contained an average amount of water, as did also the drains. Another instrument, No. 4, was attached to the trunk of a dead tree on the summit of the hill, with the bulbs at a height of 1·10 metres (3·6 feet) above the soil, which at this point was covered with long rank grass.

The observations made are contained in the following tables:—

TABLE A.

SAN PAOLO. SERIES II.

Inst. No. I.; Low Ground; Plate XVIII.

Time.	D.B.	W.B.	U.R.	Tension.	Time.	D.B.	W.B.	U.R.	Tension.
P.M.					A.M.				
6.15	27·0	22·5	66	17·49	3.0	15·0	14·0	89	11·30
6.50	26·0	23 0	76	19·04	5.0	16·5	15·5	90	12·50
7.50	22·5	20·5	82	16·71	6.15	22·0	20·0	82	16·16
8.45	20·0	18·5	86	14·93	7.30	26 5	22 0	66	16·89
9.35	19 0	17·0	81	13·20	10.0	31·0	25·0	59	19·84
10.40	18·0	15·5	77	14·32	11.30	31·5	26·0	63	21·57
12.0	17 0	15·5	85	12·19	P.M.				
A.M.					2.30	31·0	25·0	59	19·84
1.15	16·0	15·0	89	12·09	5.30	28 0	24·0	70	19·71

SAN PAOLO. SERIES II.

Inst. No. II.; Low Ground; Plate XVIII.

Time.	D.B.	W.B.	U.R.	Tension.	Time.	D.B.	W.B.	U.R.	Tension.
P.M.					A.M.				
6.15	27·2	24 2	77	20·60	3 0	16·4	16·0	96	13·29
6.50	27·0	24·8	83	21·91	5.0	16·8	16·8	100	14·24
7.50	23·4	22·2	90	19·16	6.15	21 6	20·2	87	16 75
8.45	20·8	20·2	94	17·24	7.30	24 2	21·4	77	17 23
9.35	19·6	19·0	94	15·98	10.0	29 2	25·4	72	21·76
10.40	18·2	17·8	96	14·92	11.30	31·8	26·0	61	21·39
12.0	17·8	17·5	97	14·70	P.M.				
A.M.					2.30	31·6	25·6	60	20·68
1.15	16·8	16·5	97	13·79	5.30	28·4	24·6	72	20·65

San Paolo. Series II.

Inst. No. III.; Low Ground; Plate XVIII.

Time.	D.B.	W.B.	U.R.	Tension.	Remarks.
P.M.					
6.15	28·2	25·5	79	22·58	
6.50	28·0	25·0	77	21·69	
7.50	24·5	23·0	87	19·96	
8.45	21·3	20·4	92	17·28	
9.35	20·0	19·0	91	15·73	Night very clear; dew beginning to [fall.
10.40	18·8	18·0	92	14·87	
12.0	17·8	17·0	92	13·93	
A.M.					
1.15	16·8	16·0	92	13 05	Very cold and damp.
3.0	16·2	15·7	94	12·91	Very cold and damp.
5.0	16·8	16·8	100	14·24	Instruments dripping with dew.
6.15	22·0	21·0	91	17·88	
7.30	27·8	24·5	75	20·83	
10.0	34·0*	27·0	56	21·15	
11.30	30·5	27·5	78	25·43	Hot and suffocating.
P.M.					
2.30	31·5	27·0	69	23·71	
5.30	29·5	25·5	71	21·77	Hurricane; terrific thunderstorm; vines knocked down by wind at 6 P.M.

San Paolo. Series II.

Inst. No. IV.; Hill; Plate XVIII.

Time.	D.B.	W.B.	U.R.	Tension.	Remarks.
P.M.					
6 25	27·5	21·5	56	15·39	
7.0	27·2	22·0	61	16·46	
7.40	26·0	22·0	69	17·20	
9.0	24·5	22·0	79	18·12	Damp and cold below.
9.50	21·4	20·8	95	17 91	Fresh on the hill.
10 50	21·2	20·0	89	16·65	
A.M.					
12.15	19·8	18·8	90	15·53	Very cold.
1.30	20·0	18·8	89	15·41	Bitterly cold, but pleasant.
3.15	19·0	18·0	90	14.75	
5.10	19·0	18·0	90	14.75	
6.30	22·8	20·2	78	16·01	
7.45	25·0	21·0	68	16·04	
10.15	29·3	24·0	62	18·91	
12.0	31·2	23·5	49	16 77	Delightful breeze.
P.M.					
2.45	31·0	23·6	56	17·71	
4.45	29·8	23·8	58	18 22	

* Canvas cover slipped down a little, this reading is therefore doubtful; 32° probably more correct.

TABLE B.

SAN PAOLO. SERIES II.

July 24 and 25, 1885.

	Kew.	San Paolo.			
		1.	2.	3.	4.
Mean temperature	18·7	22·9	23·2	23·3	24·6
Maximum temperature	28·5	31 5	31·8	32·0	31·2
Minimum temperature	9·7	15·0	16·4	16·2	19·0
Excursion of thermometer	18·8	16·5	15·4	15·8	12·2
Mean hourly variation of temperature	1·3	1·4	1·2	1·4	1·3
Fall of temperature per hour to minimum	1·19	1·33	1·20	1·33	0·94
Rise of temperature per hour to maximum	1·70	1·90	1·80	2·25	1.30
Mean relative humidity	67	75	83	84	71
Mean tension of aqueous vapour	10·11	18·8	19·8	17·7	16·4
Maximum ditto ditto	11·49	21·57	21·91	25·43	18·91
Minimum ditto ditto	8·39	11·30	13·29	12·91	14·75
Range of ditto ditto	3·10	10·27	8 62	12·52	4·16
Mean hourly variation of tension	0·43	1 12	0·9	1·18	0 66
		Low ground.			Hill.

The results of these observations are set out as before in a condensed form in Table B. side by side with those made at Kew during the same period. Considering, firstly, the records obtained from Nos. I., II., and III., the mean temperature recorded by the three instruments is practically the same. The same slight increase of temperature from below upwards which was found in the previous observations is again shown, and somewhat more conclusively, as we have the records of three instruments instead of two. The differences between the maxima further confirm this; the minima show that the rise of temperature is greater in the first metre above the soil than in the second, and judging from the results of Series I. and II. we might argue that the difference of temperature recorded by instruments placed at the height of 2½ metres and 4 metres respectively above the soil, would be insignificant; this is a matter to which we shall return later. For the present we will be content to observe that the excursion of the thermometer diminishes as we ascend, and that a very small elevation above the soil is suffcient to produce a very

marked effect in this direction, it is worthy of note that the mean hourly variation of temperature, and the rate of fall per hour to the minimum is the same for instruments I. and III., and that these exhibit a higher rate of change than instrument II., whilst the rate of rise to the maximum, which is practically equal for instruments I. and II., is considerably higher for instrument III.

Considering next the relation of the aqueous vapour present in the air at the different levels, we find that the mean relative humidity increases from below upwards, and that again the difference is most marked between the lower pair of instruments, whilst the range of tension is greatest in the highest pair of instruments and least in the instrument next below them ; the same applies to the mean hourly variation of tension.

Thus the middle pair of instruments indicated the highest minimum temperature, the smallest excursion of the thermometer the smallest hourly variation of temperature and of vapour tension. It is worthy of note that at 5 A.M., when Nos. II. and III. indicated complete saturation of the air with aqueous vapour, the instrument on the ground showed but 90 per cent. of the possible amount to be present.

Turning now to No. IV., the instrument placed on the hill, at the same height above the ground as No. I., but 30 metres higher above sea-level, we find a higher mean temperature, a slightly lower maximum, and a considerably higher minimum, with a markedly less excursion than in Nos. I., II., and III. The mean hourly variation of temperature was about the same, but the difference between the hourly rate of fall to the minimum and the rate of rise to the maximum is much less ; the mean of I., II., and III. gives 0°·7 C. as the difference between the hourly rate of fall and rise, whereas on the hill this difference is only 0°·36 C. or almost exactly half; that is to say, looked at from every point of view, the temperature on the hill was much more equable and free from sudden change than on the low land.

The aqueous vapour exhibits an even more marked regularity than the temperature: the mean relative humidity

was 10% lower, the maximum tension lower, and the minimum very much higher, on the hill, than on the low ground, whilst the range of variation of tension was only one-half of that recorded by No. I., and but little more than one-third of the mean range recorded by I., II., and III. together, the mean hourly rate of change of tension being at the same time scarcely more than half that recorded by the three instruments on the low ground. Thus in every way the climate of the hill, so far as temperature and moisture are concerned, was much more equable than that of the low ground, and this is well borne out by the sensations experienced at the time, as recorded under "remarks," nor is the explanation difficult; a comparison of the curves (Plate XVIII.) will suffice.

If we compare the observations at San Paolo with those made at Kew, we find that on this occasion with a lower mean temperature than at San Paolo, there was a considerably greater excursion of the thermometer. The mean hourly variation of temperature, the rate of fall per hour to the minimum, and the rate of rise to the maximum, were almost the same at the two places. The mean relative humidity was much less, the mean tension of aqueous vapour very considerably less, and the range of tension 3·1 mm. as against 4·1 mm. on the hill at San Paolo, and 11·4 the mean range of the instruments on the low ground. The mean hourly variation of tension was less than *half* that recorded by the instruments on the low ground, and *two-thirds* of that recorded on the hill, so that despite the similarity in the temperature curve the smaller proportion of aqueous vapour present in the air and the regularity of its variation would render the climate of Kew much more tolerable than the climate of the hill at San Paolo.

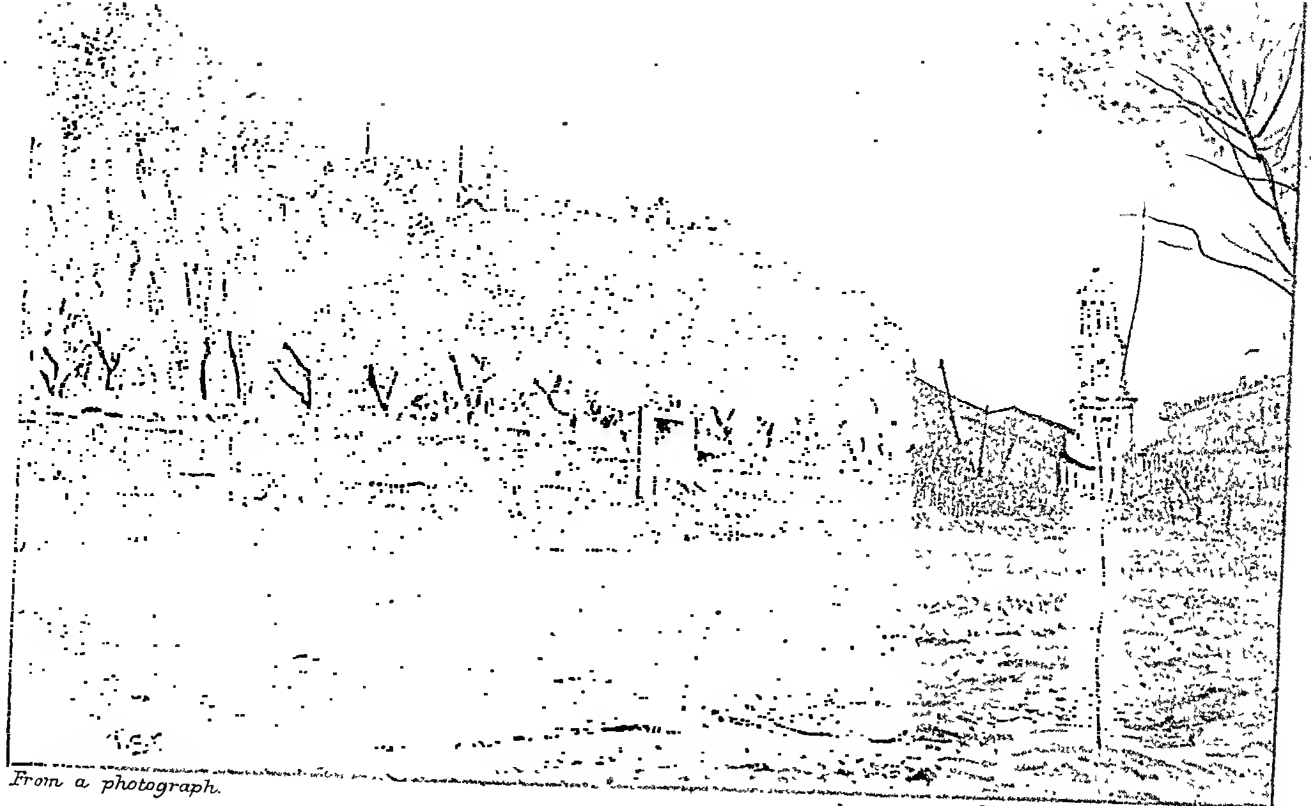
SUMMARY.

From these observations we learn that both the mean temperature and mean relative humidity increase from the surface of the soil to a height of a little over two metres above it, and that this increase is most marked in the lower strata of the atmosphere between these levels.

That at the same height above the ground but thirty metres higher above the sea, the range of temperature and of tension of aqueous vapour is very much more limited and the rate of variation of both much smaller than on low land.

That with even the same excursion of the thermometer, and the same rate of variation from hour to hour, the tension of aqueous vapour at Kew and its variations are much less than at San Paolo, and expressed as sensations experienced by a person exposed to these climates, that of the low land is distinctly uncomfortable, that of the hill comfortable, and that of Kew still more so.

It must not be lost sight of that the range of the thermometer at Kew, though greater than at San Paolo, occupies a lower position on the scale. The significance of this will be seen when we come to consider the possible effect of these variations of temperature and moisture upon the human body.



From a photograph.

London, Stanford's Geog^l. Estab^t.

VIEW OF THE BASILICA & CAMPANILE OF SAN. PAOLO FUORI LE MURA.

Shewing its relation to the tufo hill in the vineyard oppsite

SERIES III.

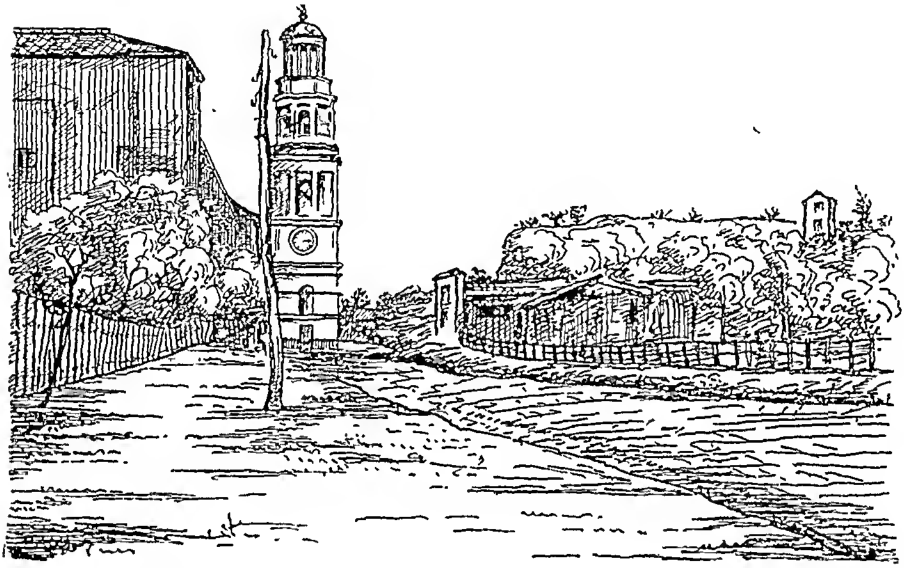
SAN PAOLO FUORI LE MURA, JULY 28 AND 29, 1885.

IN the previous observations, though one set of instruments was placed at a considerable altitude above the sea-level, the height of the bulbs above the ground was the same as before. It was obviously desirable, in the face of the well-known practice of the inhabitants of malarious countries of elevating their houses as much as possible above the level of the surrounding country, to expose a pair of instruments at a considerable altitude above the soil.

The tower of the Basilica afforded the necessary conditions, with the additional advantage that one of the large arches was in such a position as to enable an instrument to be placed at almost exactly the same level, above the sea, as the one on the top of the hill in the previous experiment, the difference being that whilst the latter was 1·30 metres (4·26 feet) above the soil, the former was 31 metres (104·9 feet). The level was determined by clinometer, the horizontal distance between the two points being almost exactly 200 metres (218·7 yards). (Plate XIX.).

In this series, the need of skilled assistance was perhaps more felt than in any. It would have been exceedingly interesting to have made simultaneous observations on the tower and on the hill, but inasmuch as the journey from the tower to the level of the road through the corridors of the monastery involved the descent and ascent of no less than 806 steps, the physical exertion and the time required, was more than sufficient without adding to it the ascent and

descent of the hill. Besides this, in order to leave the monastery and enter the vineyard opposite, it was necessary to twice unlock and lock again two pairs of ponderous wooden gates. With these difficulties in the way, it was thought best to confine the observations to the monastery, placing one pair of instruments (No. I.) in the garden (Orto), in the same position as in Series I., 1·30 metres above the soil. Another pair (No. II.) in the centre of one of the arches of the



CAMPANILE OF THE BASILICA OF SAN PAOLO FUORI LE MURA.
Showing the position of the Tufo Hill and Osteria opposite. From the Via Ostiense, looking towards Rome. (*From a photograph.*)

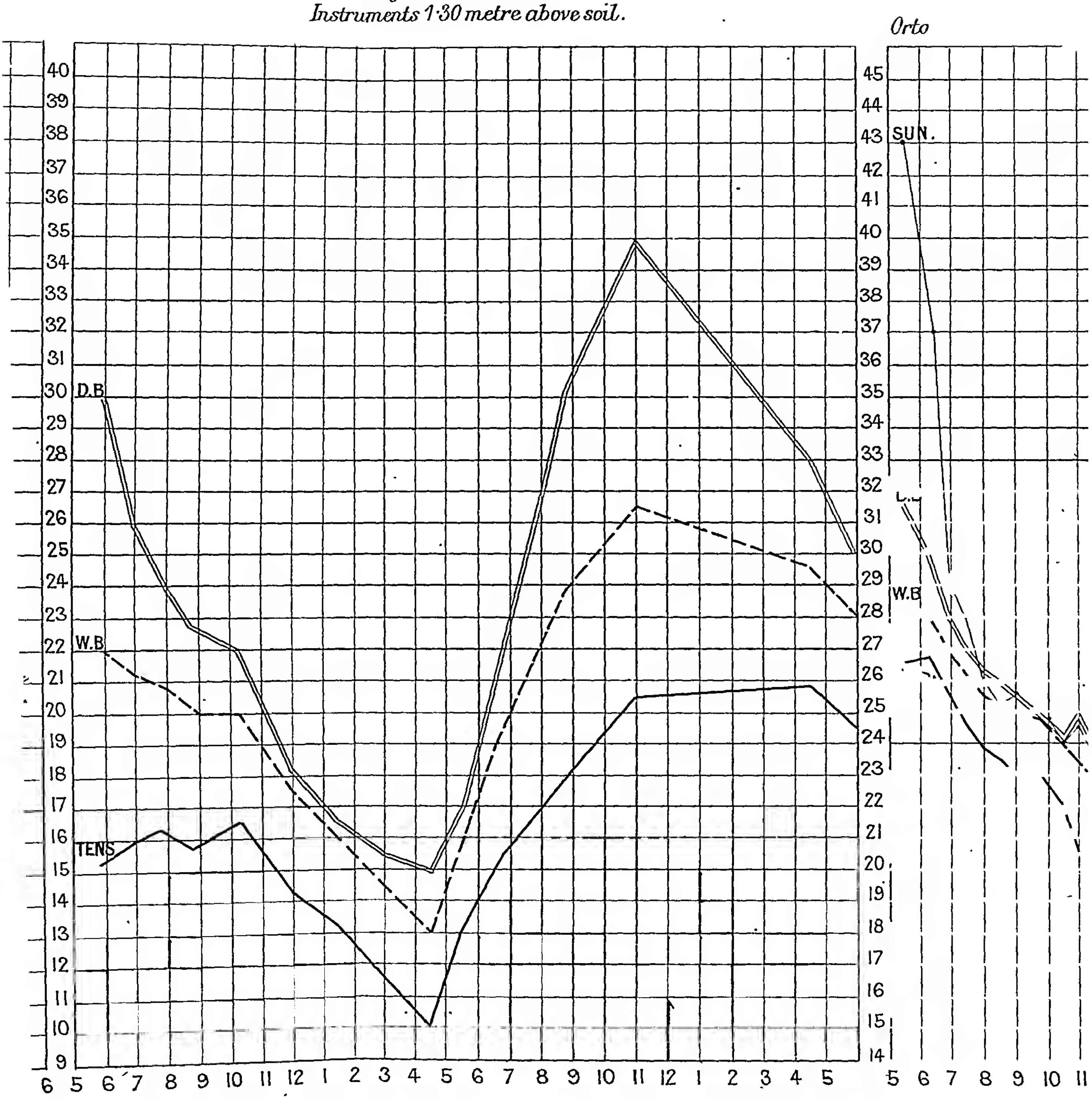
Campanile, which, as before said, was at the same height above the sea-level as the top of the hill in the vineyard opposite. The distance to be traversed, and the great number of steps to be ascended and descended, rendered these observations excessively laborious, and the time occupied in making each journey was so great that the number of observations was necessarily much smaller than in the previous series.

The following tables exhibit the results obtained :—

GARDEN OF SAN PAOLO FUORI LE MURA.

July 28-29-1885.

Instruments 1·30 metre above soil.



San Paolo. Series III.

Inst. I.—(Orto); Plate XX.

Time.	D.B.	W.B.	U.R.	Tension.	Remarks.
P.M.					
5.50	29·8	22·2	49	15·22	
7.0	26 0	21·3	64	15·96	
7.50	24·0	20·8	74	16 31	
8.45	22·8	20·0	76	15·67	
10.15	22·0	20·2	84	16·51	
12.0	18·2	17 4	92	14·30	Bitterly cold.
A.M.					
1.30	16·5	16·0	95	13·23	Very heavy dew.
3.0	15 5	14·5	89	11·69	
4.30	14·8	13·0	80	10·07	
5.30	17 0	16·0	90	12·93	
6.45	21·8	19·5	80	15·45	
8 45	30 2	23·8	56	17·97	
11.0	35·0	26·5	49	20·46	
P.M.					
4.30	28·0	24·5	74	20·70	Heat suffocating.
6.0	25·0	23·0	83	19·65	Clouded over.

San Paolo. Series III.

Inst. II.—Campanile; Plate XX.

Time.	D.B.	W.B.	U.R.	Tension.
P.M.				
6.0	26·6	22·8	71	18·29
7.15	25·4	22 8	79	19 04
8.0	25·0	22·6	80	18·91
9.0	24·8	22·2	79	18·30
10.30	23·2	21 6	86	18·20
11.45	21·2	20·2	91	17·00
A.M.				
1.15	21·0	19·8	89	16 45
2.45	19·8	18·0	83	14·26
4.15	19·4	18·2	88	14·82
5.15	18·6	17·6	90	14·37
6.30	20·0	18·6	87	15·09
8.30	24·4	22·6	85	19 28
11.30	27·2	23·4	71	19·06
P.M.				
4.0	24·2	22·6	86	19·41
5.30	25·5	24·5	92	22·25

TABLE B.

July 28 and 29, 1885.

	Kew.	San Paolo.	
		1.	2.
Mean temperature	16·0	23·1	24·7
Maximum temperature	19·0	35·0	27·2
Minimum temperature	14·4	14·8	18·6
Excursion of thermometer	4·6	20·2	8·6
Mean hourly variation of temperature	0·4	1·9	0·9
Fall of temperature per hour to minimum	0·35	1·25	0·72
Rise of temperature per hour to maximum	0·65	3·10	1·43
Mean relative humidity	59	75·6	83·8
Mean tension of aqueous vapour	8·03	15·74	17·65
Maximum ditto ditto	9·36	20·70	22·25
Minimum ditto ditto	7·29	10·07	14·37
Range of ditto ditto	2·07	10·63	7·88
Mean hourly variation of tension	0·19	0·90	0·64
		Garden	Tower.

Considering as before the collected results in Table B. The difference between the mean temperatures on the tower and in the garden respectively, is only 1°·6 C., and had we only these figures to guide us, we might suppose that there was no important difference between the two places, whereas in truth the very reverse was the case; the maximum in the garden was 7°·8 C. above the maximum on the tower, and the minimum 3°·8 C. lower, that is to say, the excursion of the thermometer in the garden was 20°·2 C., and that on the tower only 8°·6 C., or a difference of range amounting to no less than 11°·6 C. (20°·8 F.).

The mean hourly variation of temperature in the garden was 1°·9 C., and on the tower 0°·9 C., or barely half the amount; the fall of temperature per hour to the minimum in the garden was 1°·25 C., on the tower 0°·72 C., again but little more than one-half, whilst the rise of temperature per hour to the maximum in the garden was 3°·10 C. as against 1°·43 C. on the tower, a ratio of 2·16 : 1.

So far then as temperature is concerned, the differences between the garden and the tower are well defined and striking.

AQUEOUS VAPOUR.

The mean relative humidity on the tower was 83·8, in the garden 75·6—that is to say, throughout the period of the observations the air at the level of the instruments on the tower (31 metres above soil) was more highly charged with aqueous vapour than that of the garden. The maximum tension was slightly higher, and the minimum tension very considerably so, viz. 14·37 mm. as against 10·07 mm. in the garden ; but the range of tension at the latter level was 10·63 mm. against 7·88 mm. on the tower, which constitutes a very considerable difference.

Considering the mean hourly variation of tension, we find that it was 0·90 mm. in the garden, and 0·64 mm. on the tower, or a ratio of 3 : 2, showing that the climate of the garden so far as aqueous vapour is concerned was much less uniform than that of the tower. The nature of the changes is well illustrated by the alterations in clothing which the author found it necessary to make during the night in order to keep reasonably warm. During the day, a suit of flannel with a canvas coat and a sun helmet made the suffocating heat more or less tolerable, but no sooner did the sun show signs of setting than the change of temperature made additional clothing a necessity. On this particular occasion a waistcoat (not worn during the day) was found to be comfortable at 7 P.M.; by 9 o'clock a cardigan jacket was added without discomfort, from this till midnight and later, a thick woollen shawl thrown over the shoulders, scarcely sufficed to prevent the cold being felt ; whilst in the two hours before dawn, and for an hour or more afterwards, it was absolutely necessary to wrap the shawl closely round the body, to throw a heavy rug round the shoulders, and to substitute a close-fitting felt hat for the helmet. These details will show more clearly than the curves and figures of the observations how great are the changes experienced within a very short period of time in the Roman Campagna in summer. At Tre Fontane, and subsequently on the Isola Sacra, it was found necessary to wear a macintosh-

cape and jack-boots in order to protect the body from the dew. The author has passed many nights in the open in England, but has never experienced such discomfort as during these investigations in the Roman Campagna. The rapid fall of temperature after sundown combined with the great variation in the tension of aqueous vapour seem to produce conditions much more trying than uniformly great cold or heat, and this is particularly the case in the hour just before dawn and for a short time after. The heat of the day made the approach of night most welcome, but no sooner had the sun gone down, than the rapid fall of the temperature, and chilling dew, caused an equally pleasurable anticipation of the dawn, though hardly had the sun appeared above the horizon than it became evident that there was after all but a choice between two evils.

If we examine the record of the instrument in the garden, the extent and nature of these variations becomes more apparent. The minimum temperature (14°·8 C.) occurred at 4.30 A.M., and from sunset the night before to this time the thermometer fell nearly 10° C. (18° F.), or about 1°·20 C. per hour. The temperature *rose* 7° C. (12°·6 F.), or 3°·5 C. per hour, between 4.30 A.M. and 6.45 A.M. and between 6.45 A.M. and 8.45 A.M. no less than 8°·4 C. or 4°·2 C. per hour, the total excursion of the thermometer at Kew on the same days being only 4°·6 C.—that is to say, the difference between the maximum and the minimum at Kew, was only equal to the difference between the temperatures at 6 A.M. and 7 A.M. at San Paolo.

The tower of the Basilica afforded an excellent opportunity for observing the distribution of the mist which covers the Campagna in the early morning, and concerning the fever-giving qualities of which so much has been said and written. On this occasion, at a quarter after four A.M. the mist, thick and white, covered all the low land excepting those parts close to the road. The immediate vicinity of the river appeared also to be more or less free, whilst but a few metres from the bank it was as dense as in any other part. Towards Rome, the mist thinned away, and the city appeared to rise out of it

surrounded by a belt in which the mist was so slight that the details of the houses outside the walls were plainly visible from the tower. The distribution of the mist was such as to indicate the existence of an intimate relation between it, and the extent to which the land was covered with buildings. It was further observed that when the sun rose and the mists began to be dissipated, they lingered longest on the uncultivated, open land; in fact, the undrained and uncultivated land was mapped out in mist in a most remarkable manner. This was particularly the case along the road in the immediate neighbourhood of the Basilica, which is here paved with lava blocks, the mist appearing to cease almost suddenly at the fences which bounded it.

Comparing the observations at Kew with those made at San Paolo, we find a mean temperature of 16° C. as against 23°·1 C. in the garden, a maximum of 19° C. as against 35° C., and a minimum almost identical in the two places; whilst the excursion of the thermometer at Kew was only 4°·6 C., as against 20°·2 C. in the garden of the monastery at San Paolo. The mean hourly variation of temperature was 0°·4 C., or almost exactly *one-fifth* of the variation at San Paolo; the fall per hour to the minimum was 0°·35 C., or rather more than *one-fourth* of that in the garden, and almost exactly *one-half* that on the tower; the rise of temperature per hour to the maximum at Kew was 0°·65 C., in the garden at San Paolo 3°·1 C., just *five times* as much; on the tower it was 1°·43 C., or a little more than *twice* the rate of rise at Kew. The mean relative humidity at Kew was only 59 as compared with 75·6 and 83·8 in the garden and on the tower at San Paolo respectively. The mean tension of aqueous vapour at the two places presents a very striking difference, that at Kew being almost exactly *one-half* of the mean of the two sets of observations at San Paolo, whilst the range of tension of aqueous vapour was but 2·07 mm. as against 10·63 mm. in the garden of the monastery, and 7·88 mm. on the tower.

Lastly, the mean hourly variation of tension at Kew was 0·19 mm., whilst at San Paolo it was 0·90 mm. and 0·64 mm. in the garden and on the tower respectively.

The differences between the climate at Kew and that of San Paolo are thus very strikingly contrasted in these observations; the variations of temperature and tension of aqueous vapour at the former place being altogether inconsiderable and exceedingly regular, whilst at San Paolo they were extreme and violent. It may be urged that it is not altogether fair to compare observations of this kind made in two different places at the same time, and that the differences found to exist may be accidental and do not constitute a true measure of the differences between the climates of the two localities. That there is a certain amount of justice in this objection cannot be denied, and if it could be shown that the records at Kew on the particular days were exceptional, any deductions based upon a comparison of the records obtained at the two places would be valueless, but this is in no sense the case; the mean daily range of temperature at Kew during the month of July, 1885, was 10°·6 C., and the mean of thirteen of the greatest excursions is but 14°·0 C., whilst the mean daily range of temperature observed at San Paolo as calculated from the series of observations made there was 17°·6 C.

A range of 16° C. is very exceptional in England, whereas in the Roman Campagna it is the rule, and does not even represent the monthly mean.

SERIES IV.

SAN PAOLO FUORI LE MURA. AUGUST 3 AND 4, 1885.

THESE observations were made with a view to testing the rationale of the custom which prevails in all malarious countries, and of which many examples are to be found in the Roman Campagna, viz. that of building large farm-houses and similar structures intended to house a considerable number of persons, around the four sides of a quadrangle, with all the windows opening upon it, those on the outer walls being very few in number, high up, and practically mere slits for ventilation. The farm-house at Santa Maria di Galera is a very excellent example of this mode of construction; it is situate in a peculiarly unhealthy locality, about a mile from the site of the ancient Galera already described (page 87).

Whatever may have been the origin of this method of construction, whether as a defence against human foes, which is possible, or against the malaria, the present inhabitants of this homestead are apparently of opinion that considerable protection against the disease is afforded by it, as they regard the exclusion of the mists and the direct influence of the wind from the surrounding country as a matter of importance. It appeared to the author that there was possibly another and similar reason for their use, viz. that by inclosing a space with buildings in such a way as to prevent the direct access of the prevailing winds, in all probability a more uniform temperature was secured, and the inhabitants of the inclosure to some extent better protected from the rigours of the climate,

than they would be if their dwellings had been isolated and built in the usual manner. It will be well to remark here that in these places the number of inhabitants is often considerable, and that the ground floor is generally used as stables, shops, storehouses and the like, the living rooms of the occupants being almost entirely on the upper floors and elevated considerably above the level of the ground. The inclosure is usually more or less well paved, and there can be no doubt that in the summer, the temperature of the interior of such a courtyard would be less variable than that of the open country, and, inasmuch as the walls of these buildings are usually very thick, the variations of temperature in the dwelling rooms would be exceedingly small. These were the advantages claimed by the occupants of the farm-buildings at Santa Maria di Galera and it appeared to the author to be desirable to examine the actual changes which took place under these conditions and to compare them with the external variations. For this purpose the buildings at San Paolo were well adapted, there being a court-yard (marked C on the map) and a large barn between this and the garden which would serve for testing the effect of mere thickness of wall as a regulator of temperature.

The instruments were placed as follows.

No. 1; in the sun 1·6 metres above the ground.

No. 2, in the shade 1·10 metre above the ground; these were planted in middle of the Orto attached to the staff as before described.

No. 3, was attached to the stem of a very tall eucalyptus tree in the Cortile (C on the map) between the Orto and the road; this tree had no branches lower than 3·5 metres from the ground.

No. 4, was hung against the inner wall of a large barn between the Cortile (court-yard) and the garden. This barn had a very large door at one end, and an almost equally large window at the other, besides two large windows opening into the court-yard, none of them glazed, so that the ventilation was very perfect.

The observations made are contained in the following tables.

TABLE A.

SAN PAOLO. SERIES IV.

Inst. II. (Orto); Plate XX.

Time.	D.B.	W.B.	U.R.	Tension.	Time.	D.B.	W.B.	U.R.	Tension.
P.M.					A.M.				
5.30	31·6	28·4	77	26·77	3.0	25·0	24·6	97	22·75
6.15	30·0	28·0	85	26·86	4.30	25·0	25·0	100	23·55
7.0	28·0	26·8	91	25·45	4.45	24·0	23·6	97	21·42
7.30	27·2	26·2	92	24·67	5.15	23·4	22·8	95	20·27
8.0	26·4	25·6	94	23·91	5.30	23·4	22·8	95	20·27
8.30	26·0	25·3	94	23·53	8.15	26·2	24·8	89	22·41
9.0	25·5	25·0	96	23·24	9.45	28·0	26·0	85	23·75
9.45	25·0	24·8	98	23·15	10.15	27·4	25·8	87	23·70
10.30	24·2	24·0	98	22·06	12.0	31·0	22·6	46	15·21
11.0	24·8	23·4	88	20·54	P.M.				
12.0	22·5	22·4	99	20·09	12.45	33·2	28·2	67	25·32
A.M.					1.45	34·6	28·6	62	25·36
12.30	22·4	22·2	98	19·78	2.30	36·0	29·6	60	26·87
1.30	22·6	22·4	98	20·02	3.0	33·8	27·8	61	24·04
2.15	22·4	22·0	96	19·41					

TABLE A.

SAN PAOLO. SERIES IV.

Inst. III. (Cortile); Plate XX.

Time.	D.B.	W.B.	U.R.	Tension.	Time.	D.B.	W.B.	U.R.	Tension.
P.M.					A.M.				
5.30	30·0	25·5	68	21·46	3.0	26·2	24·5	86	21·81
6.15	29·0	25·0	71	21·07	4.30	24·6	24·0	87	21·80
7.0	28·5	25·0	84	22·31	4.45	24·5	23·2	87	20·22
7.30	28·0	25·0	77	21·69	5.15	23·8	22·5	89	19·46
8.0	27·0	24·5	80	21·32	5.30	24·0	22·5	87	19·34
8.30	26·5	24·8	86	22·22	8.15	27·0	23·5	73	19·37
9.0	26·5	24.6	85	21·82					
9.45	25·5	24·0	88	21·26	10.15	28·8	24·8	71	20·79
10.30	25·0	24·0	92	21·57	12.0	32·0	25·5	57	20·23
11.0	25·0	24·0	92	21·57	P.M.				
12.0	24·6	23·5	91	20·85	12.45	34·0	27·0	56	21·15
A.M.					1.45	37·0	26·8	—	—
12.30	24·5	23·3	90	20·53	2.30	37·5	26·5	—	—
1.30	23·5	22·5	91	19·64	3.0	32·8	24·0	45	16·75
2.15	24·5	23·0	87	19·96					

TABLE A.

San Paolo. Series IV.

Inst. I. Sun—(Orto); Inst. IV. Barn : Plate XX.

Time.	Sun.	Barn.	Remarks.
P.M.			
5.30	43·0	28·5	
6.15	37·0	—	
7.0	29·0	—	
7.30	28·0	—	
8.0	26·0	27·5	Wind—fresh—few clouds.
8.30	25·3	27·2	Clear.
9.0	25·5	27·2	
9.45	25·0	27·2	
10.30	24·0	27·0	
11.0	24·6	26·8	Dew.
12.0	22·5	26·2	
A.M.			
12.30	22·0	26·2	
1.30	22·3	26·0	Cold—lightning.
2.15	22·5	26·2	Cloudy—thunder—lightning.
3.0	25·0	26·5	Cloudy—lightning—scirocco.
4.30	24·0	26·5	Dawn—clear.
4.45	24·0	26·5	Sky half clouded.
5.15	23·0	26·2	
5.30	23·2	26·0	
8.15	27·0	26·5	Cloudy.
9.45	30·0	—	Cloudy—suffocating scirocco.
10.15	29·2	26·5	Scirocco very suffocating.
12.0	36·0	26·8	Scirocco.
P.M.			
12.45	41·0	27·0	Clear.
1.45	45·0	27·0	
2.30	44·0	27·0	
3.0	39·0	27·0	

TABLE B.

August 3 and 4, 1885.

	Kew.	San Paolo.			
		Orto.	Cortile.	Sun.	Barn.
		2.	3.		
Mean temperature	14·4	27·0	27·7	29·1	26·7
Maximum temperature	19·5	36·0	37·5	45·0	28·5
Minimum temperature	10·1	22·4	23·5	22·0	26·0
Excursion of thermometer	9·4	13·6	14·0	23·0	2·5
Mean hourly variation of temperature	0·78	1·4	1·4	2·7	0·24
Fall of temperature per hour to minimum	0·55	1·31	0·93	3·0	0·31
Rise of temperature per hour to maximum	1·04	1·10	1·07	1·70	0·22
Mean relative humidity	68	83	80		
Mean tension of aqueous vapour	8·12	22·75	20·75		
Maximum ditto ditto	8·90	26·80	22·31		
Minimum ditto ditto	7·42	15·21	16·75		
Range of ditto ditto	1·48	11·59	5·56		
Mean hourly variation of tension	0·33	1·82	0·81		

Considering as we have done in the previous observations the collected results in Table B we find as follows.

The temperature recorded on these two days was almost the highest experienced throughout the whole of these investigations. The mean temperature in the court-yard was 27° C. and in the garden 27°·0 C. with a maximum of 37°·5 C. (99°·5 F.) in the former and 36°·0 C. (96°·8 F.) in the latter. The excursion of the thermometer was very much less than usual, viz. 14°·0 C. (25°·2 F.) in the court-yard, and 13°·6 C. (24°·4 F.) in the garden. Unfortunately the results are largely vitiated by the prevalence during a great portion of the twenty-four hours, of the S.W. wind or scirocco, which considerably interfered with the excursion of the thermometer.

The mean hourly variation of temperature was the same in both cases, 1°·4 C. The hourly fall of temperature to the minimum was 0°·93 in the court-yard, and 1°·31 in the garden, the rise per hour to the maximum was 1°·07 C. in the former and 1°·10 C. in the latter, so that in spite of the defect mentioned

in the whole of the observations, the rate of change in the court-yard was less than in the garden.

Aqueous Vapour.—The mean relative humidity was 80% in the court-yard, and 83% in the garden, with a mean tension of 20·75 mm. and 22·75 mm. in the two places respectively. It is in the range of tension of aqueous vapour, that the difference between the court-yard and the garden is most apparent, the actual range being in the former 5·56 mm. and in the latter 11·59 mm. or almost exactly double.

The same may be said of the mean hourly variation of tension, so that in this particular case the chief advantage of the closed court-yard over the open garden consists in the greater constancy of the amount of aqueous vapour present in the air; at the same time the court-yard showed a slightly slower fall of temperature to the minimum.

The record of the thermometer placed in the barn shows very strikingly the value of a thick wall in maintaining a constant temperature; the mean was 26°·7 C. (80° F.) the maximum 28°·5 C. (83°·3 F.), the total excursion only 2°·5 C. (4°·5 F.) the mean hourly variation of temperature was 0°·24 C. (0°·43 F.) the fall per hour to the minimum 0°·31 C. (0°·54 F.) and the rise per hour to the maximum 0°·22 C. As a matter of fact, although the temperature in the barn was considerable throughout the whole period (twenty-four hours) it appeared to be very much cooler than the external air, and at a time when the external temperature differed from the minimum in the barn by but two or three degrees the absence of damp made the change exceedingly pleasant. The record of the thermometer exposed to the sun can only be regarded as very approximate, the temperature, 45° C. (114° F.) only serves to show how great the real sun-temperature probably was, whilst the range of temperature recorded by this instrument viz. 23° C. (41°·F.) can only be taken to mean that it was *at least* this, the actual range was probably much greater.

In spite of the effect of the sirocco in diminishing the excursion of the thermometer at San Paolo, and consequently depriving the curve of one of its chief characteristics, a comparison of the records obtained with those of the Kew

Observatory still brings out in strong relief the differences between the climate of the two places. The mean temperature at Kew was 12°·6 C. (22°·6 F.) lower than at San Paolo the maximum 16°·5 C. (29°·7 F.), and the minimum 12°·3 C. (22°·1 F.) lower. The excursion of the thermometer was almost exactly two-thirds of that in the garden, the mean hourly variation of temperature barely more than half, and the rate of fall to the minimum, considerably less than half that recorded by the instrument in the garden of the monastery, though the rate of rise to the maximum was practically the same.

The greatest differences between the two sets of observations is again in the relations of the aqueous vapour. The mean relative humidity at Kew, was 1·15 per cent. less than at San Paolo, the mean tension of aqueous vapour at the latter place was only 8·1 mm. as compared with 22·7 mm. at the former, whilst the range of tension at San Paolo was almost exactly *eight* times, and the mean hourly variation about *six* times that observed at Kew.

As will be seen from the remarks in the tables there was a violent thunderstorm, after midnight, though without local rain. This with the scirocco already mentioned made it desirable to repeat the observations; this was accordingly done on August 6th and 7th.

SERIES V.

SAN PAOLO FUORI LE MURA. AUGUST 6 AND 7, 1885.

THE position of the instruments in these observations was precisely the same as in the last.

The results are recorded in the following tables :—

TABLE A.

SAN PAOLO. SERIES V.

Inst. II.—Orto.

Plate XX.

Time.	D.B.	W.B.	U.R.	Tension.
P.M.				
6.0	29·0	26·0	78	23·13
7.0	28·0	26·4	88	24·59
7.30	26·0	25·0	92	22·93
8.30	25·2	23·6	87	20·68
9.0	25·0	23·8	90	21·18
9.30	24·8	23·1	86	19·97
10.0	24·8	22·6	82	19·03
10.30	23·2	21·4	84	19·85
11.0	23·0	21·3	85	17·80
11.30	22·0	21·2	93	18·23
12.0	21·8	21·0	93	18·00
A.M.				
12.30	22·2	21·2	91	18·11
1.30	22·5	22·0	96	19·35
2.0	24·0	21·8	81	18·06
2.30	22·4	21·4	91	18·34
3.15	20·6	20·4	98	22·06
3.45	20·2	19·8	96	16·93
4.15	21·0	20·2	93	17·12
4.45	19·8	19·5	97	16·67
5.45	20·8	19·8	91	16·57
6.45	23·6	22·0	86	18·67
9.0	33·0	25·2	51	19·00
12.0	37·6	27·2	**76**	**20·40**
P.M.				
12.30	37·6	27·4	**74**	**20·14**
3.0	38·2	28·8	**80**	**23·62**
4.0	37·5	27·5	**77**	**21·11**
5.0	35·4	27·4	52	21·80
6.0	33·0	28·2	68	25·44

TABLE A.

SAN PAOLO. SERIES V.

Inst. III.—Cortile.

Plate XX.

Time.	D.B.	W.B.	U.R.	Tension.
P.M.				
6.0	30·0	25·0	65	20·46
7.0	28·8	25·0	72	21·20
7.30	28·2	24·0	69	19·59
8.30	27·5	25·0	81	22·00
9.0	27·2	23·5	72	19·25
9.30	26·8	23·5	74	19·50
10.0	27·0	22·0	63	16·58
10.30	26·2	21·0	60	15·30
11.0	26·0	20·8	60	15·08
11.30	24·8	21·5	73	17·05
12.0	24·5	22·0	79	18·12
A.M.				
12.30	24·0	21·5	72	16·92
1.30	25·0	23·0	83	19·65
2.0	25·0	22·8	82	19·28
2.30	24·0	21·6	80	17·71
3.15	23·0	20·8	81	16·92
3.45	23·0	21·0	83	17·27
4.15	22·0	20·2	84	16·51
4.45	22·0	20·4	86	16·85
5.45	22·2	21·0	89	17·76
6.45	24·0	21·5	79	17·54
9.0	32·5	21·5	34	12·30
12.0	38·0	24·5	**59**	**13·61**
P.M.				
12.30	38·2	25·0	**65**	**15·43**
3.0	39·4	25·6	**70**	**17·14**
4.0	37·5	25·0	**67**	**15·86**
5.0	35·0	24·5	39	16·38
6.0	33·0	23·5	42	15·66

TABLE A.

SAN PAOLO. SERIES V.

Inst. I. Sun—(Orto); Inst. II. Barn; Plate XX.

Time.	Sun.	Barn.	Remarks.
P.M.			
6.0	31·5	28·2	Cloudy—wind.
7.0	29·0	28·0	
7.30	27·0	27·5	Horizon N.E. to N.W—cloudy.
8.30	25·0	27·0	Clear—slight breeze.
9.0	25·5	27·0	
9.30	25·0	27·2	Clear—slight breeze.
10.0	25·5	27·0	Clear—fresh and cool.
10.30	24·0	27·0	Begins to feel cold—no dew.
11.0	23·5	26·5	
11.30	22·0	26·5	
12.0	21·5	26·2	
A.M.			
12.30	22·4	26·2	Wind.
1.30	22·5	26·5	
2.0	24·0	26·2	Strong warm wind.
2.30	22·0	26·0	A few drops of rain—cooler.
3.15	20·2	26·0	Cold—no dew.
3.45	20·0	19·0*	Wind very cold.
4.15	21·0	19·0*	Dawn.
4.45	19·5	18·0*	
5.45	21·0	19·5	Splendid morning.
6.45	29·0	25·0	
9.0	45·0	—	
12.0	46·0	—	Strong wind.
P.M.			
12.30	46·2	30·0	
3.0	42·5	31·0	
4.0	46·2	30·5	
5.0	41·6	—	
6.0	36·5	29·0	

* On the ground under No. 1.

TABLE B.

San Paolo Fuori le Mura.

August 6 and 7, 1885.

	Kew.	San Paolo.			
		Orto.	Cortile.	Sun.	Barn.
		2.	3.		
Mean temperature	13·8	26·5	28·3	27·7	26·4
Maximum temperature	18·6	38·2	39·4	46·2	31·0
Minimum temperature	10·1	19·8	22·0	19·5	25·0
Excursion of thermometer . .	8·5	18·4	17·4	26·7	6·0
Mean hourly variation of temperature	0·83	1·7	1·5	2·8	0·5
Fall of temperature per hour to minimum	0·54	0·85	0·80	1·11	0·03
Rise of temperature per hour to maximum	0·94	1·80	1·58	3·3	0·55
Mean relative humidity . . .	82	84	69		
Mean tension of aqueous vapour	9·61	19·95	17·39		
Maximum ditto ditto . .	11·96	25·44	22·00		
Minimum ditto ditto . .	7·91	16·57	12·30		
Range of ditto ditto . .	3·15	8·87	9·70		
Mean hourly variation of tension	0·54	1·68	1·60		

The comparison between the temperature in the two positions does not in this case yield any very striking results. The mean temperature of the court-yard was higher than that of the garden, as was the maximum, which reached 39°·4 C. (103° F.). The excursion of the thermometer in the garden was greater than in the court-yard, as was also the mean hourly variation of temperature. The fall per hour to the minimun was almost the same in both cases; whilst the rate of rise to the maximun was distinctly slower in the court-yard than in the garden, so that the temperature in the former was slightly more equable than in the latter; this is shown more particularly in the difference of the readings at 6.45 A.M. and 9.0 A.M. in the two places.

Aqueous Vapour.—The relations of the aqueous vapour present more important differences. In the court-yard the mean relative humidity was only 69°/₀ as against 84°/₀ in the garden; the mean tension of aqueous vapour was 2·5 mm. lower in the courtyard than in the garden and, though the

range was slightly greater, the mean hourly variation was the same, so that the atmosphere of the former was distinctly drier than that of the latter.

The readings of the thermometer in the barn show, as in the previous series, a very small variation from the mean and a very slow and regular rate of change.

The observations were again rendered unsatisfactory by the wind which, though not continuous, began to blow a little after midnight from S. W. by S. and ultimately from due south, affecting the thermometer very considerably especially at 2 A.M. This hot wind (the Africano) was again experienced at Tre Fontane a few days later.

A comparison of the readings at San Paolo with those at Kew brings out very forcibly the exaggerated character of the climate at the former place. The mean temperature at San Paolo was 12°·7 C. (22°·8 F.) higher than at Kew, the maximum 19°·6 C. (35°·3 F.) higher, and the excursion of the thermometer more than twice as great. The mean hourly variation of temperature at Kew was less than *half* that at San Paolo, and though the fall per hour to the minimum was 0°·54 as against 0·85, the rate of rise to the maximum was only *half* that at San Paolo. These ratios hold also for the aqueous vapour, with a mean relative humidity practically the same. The tension at Kew was only *one half* and the range of tension and mean hourly variation but *one-third* of that recorded at San Paolo.

SERIES VI.

TRE FONTANE, AUGUST 14 AND 15, 1885.

THE preceding observations having practically exhausted the neighbourhood of San Paolo, and it being desirable to extend them to other places, the apparatus was moved to the abbey of Tre Fontane two and a half kilometres ($1\frac{1}{2}$ miles) further from Rome along the Via Laurentina. The site was suitable for many reasons; firstly, by the courtesy of the abbot, the author was allowed the absolute use of a room near the gateway, in which to arrange and prepare apparatus; secondly, the estate being secluded and fenced, he was practically free from any molestation; and lastly, there was a choice of high and low land, cultivated and uncultivated, on which to place the instruments.

Let us now endeavour to describe the estate with the aid of the sketch-map (Plate XXI.)

It will facilitate description if we turn the map upside-down as regards the compass points, so that we may consider ourselves approaching the abbey from Rome along the Via Laurentina.

Just before we reach the first point indicated on the map, the road passes between low hills composed entirely of volcanic material. To our left the pozzolana is of good quality and the character of the soil and extent of the working has already been described (Page 40, Plate IX.). On our right is one of the circle of forts which have recently been erected for the defence of Rome. From the high ground on the right at this point and about fifty metres from the road we obtain the

general view of Tre Fontane shown in Plate (XXII.); continuing along the road we begin at once to descend, and about 100 metres before we arrive at the bridge and *osteria* we are on the level of the valley of the Fosso delle Tre Fontane, which is here about 250 metres wide, the Fosso flowing towards our right to join the Tiber. The abbey itself is built in an offset of this valley at about the same level, or but little higher, *i.e.* some twelve or thirteen metres above sea-level. To our left the valley is soon split into two by an isolated hill which will, before long, have been carried into Rome, as it consists of pozzolana of very excellent quality for building purposes. The stream also splits into two, which ultimately are lost on the higher open ground, where they take their rise; these streams are greatly reinforced by springs which issue from the bases of the hills and which have been before described.

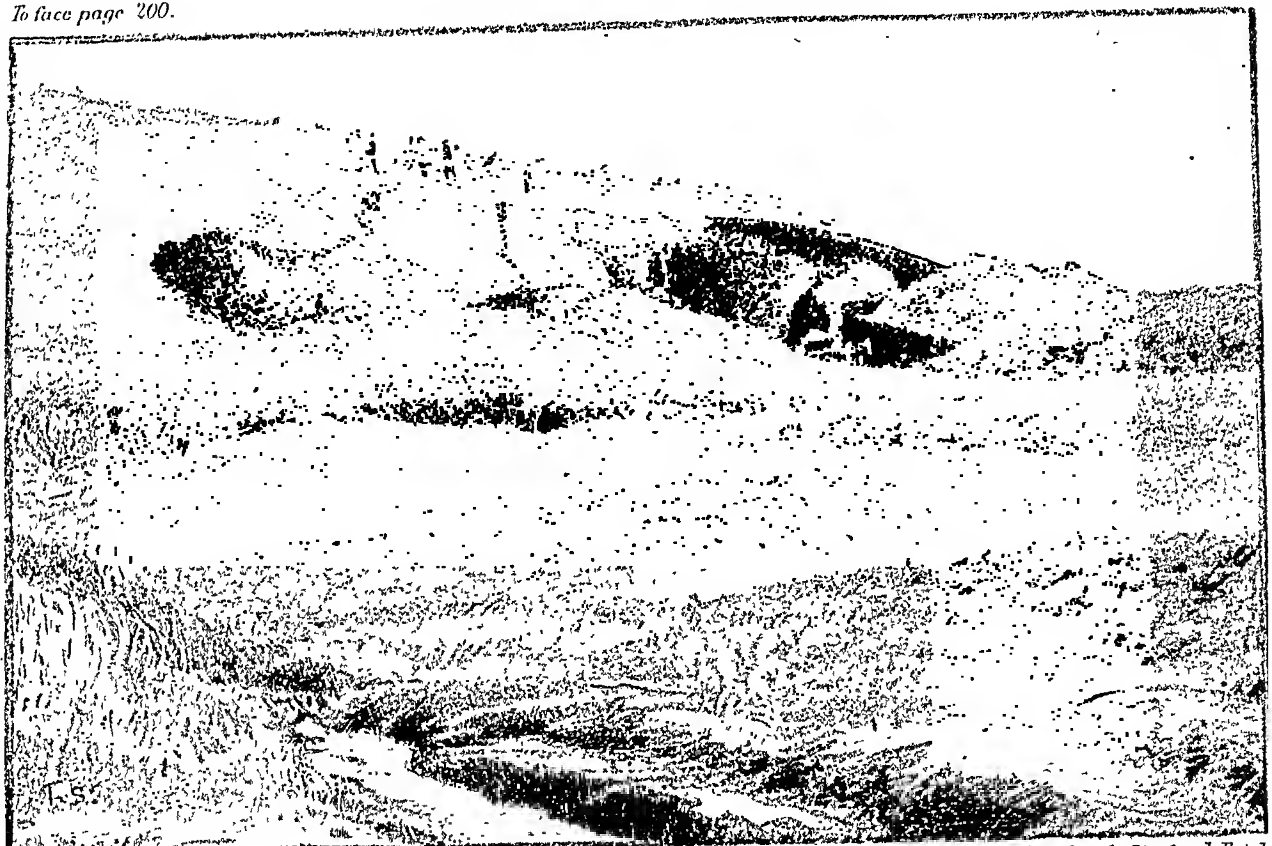
The manner in which the volcanic soil holds the water has been already referred to in the account given of the geology of the province of Rome; the mode of origin of one of the feeders of the Fosso delle Tre Fontane is a most excellent illustration in point, and will be readily understood by reference to Plate (XXIII.) from a photograph. The ground on the left of the picture and along the dark line at the base of the hill is wet and boggy from water which flows out from the base of the hill on the other side of which are situate the pozzolana workings before referred to. This water is in sufficient quantity to form within a very few metres a small stream which joins the Fosso at the lower angle of the picture. We have here an example in miniature of a state of affairs which exists over the whole Campagna. As far as the author was able to observe this small hill (it is about 250 metres in diameter at its base) was capable of holding sufficient water to maintain a continuous, though varying supply, to this short feeder of the main stream. The importance of this water-holding capacity of the volcanic soil will however be more apparent if we consider an example on a larger scale. In the year 1876 the water in the torrents in the neighbourhood of Velletri began to show an increase about October 20th; the total amount of water which had fallen over the drainage area since the first

rains of September, was equal to a depth of 25 centimetres (nearly ten inches), and represented a total amount of thirty-four millions of cubic metres of water. Thus, arguing from this example, the soil of the Campagna appears to be capable of receiving and holding almost a foot of water before it will begin to give it up to the streams.

In 1877 the flow did not begin till even later, in the first fortnight of November, after a rainfall of seventeen centimetres or twenty-three millions of cubic metres over the whole area. The quantity lost by evaporation was of course very great, but nevertheless the figures show that the water-holding capacity of the soil is enormous.

Bearing these facts in mind, it will not be difficult to understand why the bottoms of these valleys in the Campagna are often wet and boggy even in long-continued dry weather. This is especially the case in the valley of the Fosso delle Tre Fontane; even in very dry weather the soil is always wet, and the small field drains always full of water, whilst in winter, and after a very moderate rainfall, it becomes a bog. The Fosso has been banked up above the level of the surrounding land in order to prevent flooding; this is necessitated by the fact that these streams are continually raising their beds by reason of the sand and silt which they carry. In this particular case the precaution is almost useless, on account of the large quantity of water which drains on to the level from the surrounding hills, sufficient in all probability to flood the valley long before the Fosso overflowed.

The *osteria* to the left after we pass the bridge is a large new building which is deserted in summer, being only very occasionally used as a sleeping place by *contadini* employed in the neighbourhood. The hostess stated to the author that, as the result of staying until a late period of the year, she had contracted fever of so severe a type that she did not again intend to incur the risk. The road to the right has been constructed by the convicts at Ponte Buttero to join the Via Ostiense, and that portion of the Via Laurentina from the corner of this road to the osteria del Ponticello (on the map of the vicinity of San Paolo, Plate XVII.) is now rarely used



From a photograph.

London; Stanford's Geog^l Estab^t

VIEW OF POZZOLANA PITS NEAR TRE FONTANE.

because of its execrable condition and the steep gradients upon it.

It is now necessary to give a brief account of the extent and nature of the cultivation of the estate which extends a little beyond the Fosso della Cecchignola southwards and includes pasture, vineyards, and eucalyptus plantations. It is somewhat difficult to make such a description intelligible, but it will be facilitated if we take the line followed in visiting the instrument describing the features of the ground passed over.

On the sketch-map (Plate XXI.) the altitude of the land is indicated by the contours; the dotted line, with Roman numerals upon it at intervals, indicates the course taken in visiting the thermometers, and the numerals themselves show the position of the instruments.

Starting from the monastery gate and proceeding along the road towards Rome as far as the end of the wall of the monastery garden, and turning through a gateway to the right, we find ourselves on the open meadow land which has been before mentioned. Following the line indicated and rounding the base of a somewhat prominent hill, which rises some twenty metres or more (twenty-five feet) above the meadow, and whose summit and slopes are covered with eucalyptus trees, we reach instrument No. I., planted in the middle of a fenced portion of the meadow about sixty metres from the base of the hill, as far as possible from any of the open field drains, and attached to the apparatus described on page 154. At the time at which these observations were made, the grass in the meadow was short, and the soil, despite the dryness of the summer, was more or less wet and boggy. This is partly to be accounted for by the drainage from the surrounding high land, which was only imperfectly controlled by shallow ditches. Continuing along the meadow to a point where the contours between two projecting hills approach one another very closely, indicating a deep hollow, we reach a fence at which the vineyards of the monastery begin. Following the line of this valley and gradually ascending amongst the vines, we then turn to the right southwards with vineyards on both sides, descend somewhat, and crossing a small stream, not indicated

on the map, ascend again to the point marked II. Here the vineyards cease on the left, and we reach a piece of Campagna which, in 1885, had not been broken up for cultivation and was covered with short stunted herbage. To a fence which formed the boundary between this uncultivated land and the vineyards before mentioned, and at the same height from the ground as No. I. (1·10 metre) instrument No. II. was attached. Continuing southwards about 100 metres from this point, the eucalyptus plantations begin. The trees on the right are six to ten metres in height and growing somewhat closely together, whilst for some distance on the left, eastwards, they are still very young, merging into extensive plantations of much older growth which extend, beyond the limits of the map, to the western boundary of the estate. To the stem of a tall tree, in the fourth row from the foot-path which separates these old plantations from the young trees just mentioned, instrument No. III. was attached. From this point the line followed led directly back to the abbey, amongst eucalyptus trees planted in very shallow soil, over old pozzolana workings, to a hollow behind the abbey wall. To the stem of a dead eucalyptus tree in this spot instrument No. IV. was attached. It may be remarked here that the trees planted in this depression did not appear to thrive. The soil was damp, and the place so shut in by the surrounding land and the abbey buildings that there was no ventilation, and the air of this spot was in consequence during the daytime hot and oppressive, and at night cold and wet.

The four instruments whose positions have been indicated were those used in Series VI. In the next series instrument IV. was moved to a point on the open Campagna indicated by the figure V., where it was attached to a telegraph pole at the same height from the ground as before. The eucalyptus plantations terminate some distance to the northward of the dotted line indicating the footpath to the Bagno, so that this instrument, placed on almost the highest ground on the estate, was freely exposed. Another instrument was placed in the valley of the Fosso di Ponte Buttero at the point marked VI., the distance of which in a direct line from the Abbey gate is

rather more than one kilometre; Nos V. and VI. both stood over poor pasture land. The valley of the Fosso di Ponte Buttero is filled by the alluvial deposits of the streams which flow through it, whilst the mass of lithoid tufo which lies between the two feeders of the main stream is completely isolated and owes its resistance to erosion to the quantity of lime it contains, which has formed with the volcanic ash a hard and compact rock capable of offering very considerable resistance to the action of air and water. The streams flow in channels which are deep out of all proportion to the amount of water they usually carry, but the torn and twisted bushes on their banks, with their branches filled with dead grass, show that at times there is amply sufficient water to fill the channel and that the current is very considerable. The prison is built, as will be seen from the map, on comparatively low ground at the bottom of a valley inclosed on all sides by land which rises to thirty or thirty-five metres above it. About half a kilometre to south-east of the prison, at the head of the valley formed by a bend in the Fosso della Cecchignola, is the termination of a dyke of lava thrown out from the Alban volcanoes, and which is largely worked for paving sets.

From this brief description of the position of the instruments and the general character of their surroundings, we may proceed to a consideration of the results obtained.

TABLE B.

TRE FONTANE. SERIES VI.

Inst. I.—Plate XXIV.

Time.	D.B.	W.B.	U.R.	Tension.	Remarks.
P.M.					
7.15	24·6	23·4	87	20·92	
9.15	23·4	21·0	80	17·02	
11.15	20·6	19·0	85	15·37	
A.M.					
1.0	18·6	17·2	86	13·75	
3.30	20·0	18·6	87	15·09	Africano.
5.20	19·4	18·4	90	15·14	
8.30	28·0	24·0	70	19·71	
1.10	33·0	25·5	52	19·59	
3.25	31·5	25·0	57	19·53	

Inst. II.

Time.	D.B.	W.B.	U.R.	Tension.	Remarks.
P.M.					
7.40	26·6	22·0	65	16·83	
9.40	24·5	20·5	68	15·49	
11.30	21·0	18·0	73	13·52	
A.M.					
1.10	18·5	17·5	90	14·27	
3.40	20·5	17·5	73	13·05	Africano.
5.10	20·0	17·2	74	12·89	
8.40	32·0	24·0	49	17·24	
1.20	35·0	24·0	37	15·39	
3.35	33·5	23·0	37	14·41	

Inst. III.

Time.	D.B.	W.B.	U.R.	Tension.	Remarks.
P.M.					
7.45	26·7	22·8	70	18·23	
9.40	25·0	21·2	69	16·33	
11.40	22·6	19·2	71	14·46	
A.M.					
1.20	21·9	19·4	78	15·22	
3.50	21·5	19·0	78	14·81	Africano.
5.0	18·7	15·7	71	11·45	
8.50	27·0	22·0	63	16·58	
1.30	32·2	23·0	42	15·21	
3.45	32·0	25·2	55	19·62	

Inst. IV.

Time.	D.B.	W.B.	U.R.	Tension.	Remarks.
P.M.					
7.50	24·0	22·0	83	18·43	
9.45	22·0	21·0	91	17·88	
11.45	19·5	18·5	90	15·24	
A.M.					
1.30	17·8	16·8	90	13·63	
4.0	18·0	18·0	90	14·75	Africano.
4.45	18·5	17·8	93	14·74	
9.0	34·0	29·5	70	27·86	
1.40	38·0	29·5	82	25·39	
4.0	43·0	—	—	—	Sun temperature.

To face p. 204.

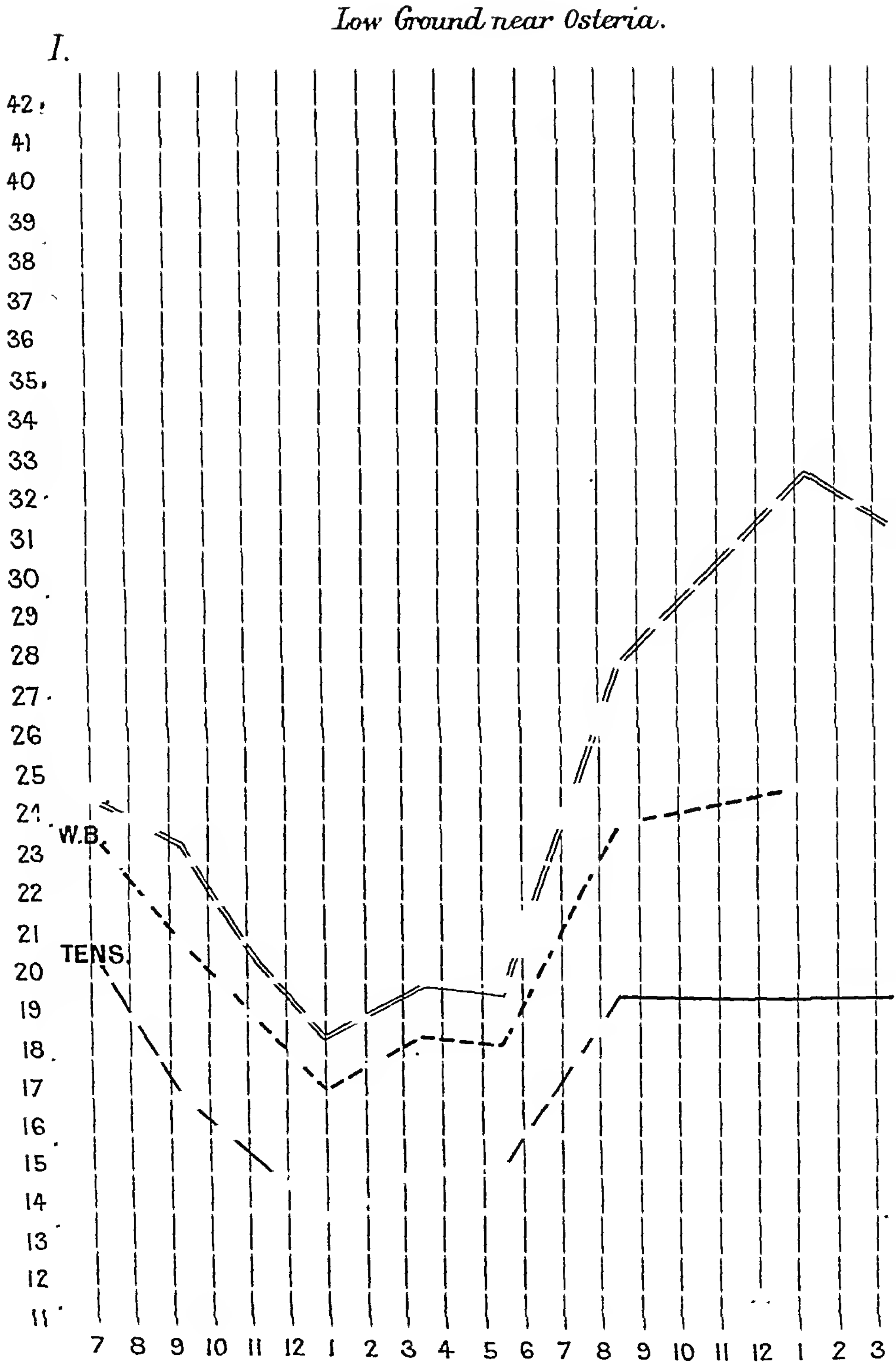

Low Ground near Osteria.
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TABLE B.

TRE FONTANE.

August 14 *and* 15, 1885.

	Kew.	Tre Fontane.			
		1.	2.	3.	4.
Mean temperature	13·9	24·3	25·7	25·2	24·1
Maximum temperature	21·8	33·0	35·0	32·2	38·0
Minimum temperature	6·7	18·6	18·5	18·7	17·8
Excursion of thermometer	15·1	14·4	16·5	13·5	20·2
Mean hourly variation of temperature	1·2	1·2	1·4	1·1	1·5
Fall of temperature per hour to minimum	1·1	0·32	0·66	0·80	0·55
Rise of temperature per hour to maximum	1·1	1·7	1·9	1·7	2·4
Mean relative humidity	65	77	62·8	66·2	86·1
Mean tension of aqueous vapour	7·38	17·34	14·78	15·76	18·49
Maximum ditto ditto	8·99	20·92	17·24	19·62	27·86
Minimum ditto ditto	6·42	13·75	12·89	11·45	13·63
Range of ditto ditto	2·57	7·17	4·35	8·17	14·63
Mean hourly variation of tension	0·55	0·66	0·63	0·96	1·07

Taking the instruments in order, No. I. showed a maximum of 33° C. (91°·4 F.) and a minimum of 18°·6 C. (65°·4 F.), that is to say, a range of 14°·4 C. (25°·9 F.). The mean hourly variation of temperature was 1°·2 C. (2°·16 F.); the fall per hour to the minimum 0°·32 C. (0°·57 F.); the rise per hour to the maximum 1°·7 C. (3°·0 F.), a rate more than five times as great as that of the fall; the range of tension of aqueous vapour was 7·17 mm. and the mean hourly variation of tension 0·66 mm. Comparing these figures with those obtained at Kew during the same period we find that the excursion of the thermometer at the latter place was a trifle greater than at Tre Fontane as shown by instrument No. I., but the maximum at Tre Fontane was 11° C. (19°·8 F.), and the mean temperature for the twenty-four hours was 10°·4 C. (18°·7 F.) higher than at Kew. The mean hourly variation of temperature at both places was the same, and it is only when we come to compare the rate of the rise and fall that the characteristic differences between the temperature curves at Kew and those of the various localities in which these observations were made, becomes apparent. At Kew the rate of rise and fall is the *same*, whereas at Tre

Fontane, as before said, the rise is more than *five* times as rapid as the fall.

Considering now the tension of aqueous vapour at the two places, we find again a characteristic difference; the maximum tension at Kew was 8·99 mm., at Tre Fontane 20·92 mm., or two and a quarter times as great. This though in some measure due to the higher temperature is not altogether accounted for by it, for we find that the mean relative humidity at Kew was 12°/o less than at Tre Fontane. Thus considering only the records of instrument No. I., we find that though the excursion of the thermometer at Kew was practically the same as at Tre Fontane, the *form* of the temperature curve was very different, the rate of change at Kew being very regular, whilst at Tre Fontane it was characteristically violent. Nor must we forget in making the comparison that the excursion of the thermometer at the two places occupics a very different place in the scale; at Kew the temperature was never more than comfortable, whilst at Tre Fontane it was well nigh intolerable, and the more so because of the large amount of aqueous vapour present in the atmosphere.

This question of the relation between temperature and moisture and the significance of the sensations produced by their combined action upon the human body is exceedingly important and will be again referred to at length. Here it will suffice to say that though the range of temperature at the two places was practically the same, the sensations experienced and the effects produced would be very different, and we shall see that observations of this kind require to be interpreted with very great care or they may lead to very erroneous conclusions.

We have now to compare the readings obtained from the four instruments one with another. The first noticeable fact is that the mean temperature recorded by Nos. I. and IV. is practically the same, whilst that of Nos. II. and III. is about a degree higher; the reasons for these differences require investigation. We find that whereas the excursion of No. I. was 14°·4 C. (25°·9 F.) that of No. IV. was 20°·2 C. (36°·3 F.), and though the minima in all four instruments are so nearly

alike that it is not worth while considering the small differences which exist, the maxima present considerable variations, and it is here that the explanation of the mean temperature is to be found. No. I. showed a maximum of 33° C. (91°·4 F.) No. IV. a maximum of 38° C. (100°·4 F.), thus illustrating in a very marked degree how very misleading records of mean temperature *only* may be. Nor is this all; the mean hourly variation of temperature in the two cases shows an important difference; in No. I. it was 1°·2 C. (2°·16 F.) and in No. IV. 1°·5 C. (2°·7 F.) the fall per hour to the minimum in No. I. was 0°·32 C. (0°·57 F.) whereas in No. IV. it was 0°·55 C. (0°·99 F.); and whereas the rise per hour to the maximum in No. I. was 1°·7 C. (3°·0 F.) in No. IV. it was 2°·4 C. (4°·3 F.). These differences come out very markedly in the respective curves (Plate XXIV.), but are also obvious when the ratios are considered. The ratio of the rate of fall per hour to the minimum, to the rate of rise per hour to the maximum, for instrument No. I. is as 1· : 5·31. In the case of instrument No. IV. this ratio is 1· : 4·36, a very consi difference. Turning now to Nos. II. and III. we find vith almost the same excursion as in No. I. (and in t of No. II. somewhat greater) the ratios are as follows, in II. 1· : 2·87 and in No. III. 1· : 2·12, that is to say, the ence of the ratio of the rate of fall to the rate of rise case of instruments Nos. I. and IV. is just about double instruments II. and III. We have thus ample justificatio asserting that the temperature recorded by Nos. II. and as very much more equable than that recorded by Nos. IV., and at the same time we can assert that the greatest actua on was recorded by No. IV.

Let us now consider the differences of condition to the instruments were exposed, and find in them if possible some explanation.

No. I. was placed over more or less damp meadow land, to some extent sheltered by surrounding high ground, but nevertheless at such a low level as to be greatly influenced by those atmospheric changes which take place at the bottom of valleys. No. IV. was placed at the back of the monastery,

amongst badly grown eucalypti, and so enclosed by the surrounding high ground and the monastery buildings as to be shut out from all active ventilation, and it was particularly noticeable throughout the whole period of observation that in this place the temperature was always extreme, hot and suffocating by day and intensely cold and damp at night. To some extent this was the case with No. I., though the fact of the valley of the Fosso delle Tre Fontane being quite open towards the Tiber probably served to mitigate these extremes, still as we have already seen they made some approach to those shown by No. IV. The records of both instruments contrast very strongly with those of No. II. and No. III., which it will be remembered were both placed upon high ground, No. II. in the open and No. III. among the eucalypti. The author's personal sensations during the period of the observations strongly confirm these differences; despite the great range of temperature recorded by No. II. the air in its neighbourhood was always fresh and pleasant, and still more so in the case of No. III. It may perhaps be said that this was precisely what might have been expected considering the position of the instruments; nevertheless it is something gained to be able to attach a numerical value to sensations not uncommonly very misleading. The effect of trees in equalizing temperature is well shown by the records of No. III., and if we compare the records of this instrument with those of No. IV. which are placed among small, and for the most part dead and sickly trees, we shall appreciate more fully the value of vigorous vegetation in this respect. The ratio of the rate of fall per hour to the minimum, to the rate of rise per hour to the maximum being, in the case of No. III. 1· : 2·12 and in the case of No. IV. 1· : 4·35.

Aqueous Vapour.—The mean tension of aqueous vapour presents some very characteristic differences, being greatest in No. IV. and least in No. II. The maximum was recorded by No. IV. and the minimum by No. III. The greatest range of tension by No. IV. and the minimum by No. II., the latter showing less than one-third of that recorded by the former; thus not only did No. II. show a fairly equable

temperature, but the small variations in the tension of aqueous vapour assisted very materially in mitigating their effect upon the body, whereas the irregularities of No. IV. already shown to have been very great, were immensely aggravated by irregularities in the tension of aqueous vapour, a most important factor in determining the sensations of heat and cold and their effects upon the body.

The mean relative humidity exhibited by the four instruments places them in the following order, IV. I. III. II., so that in every respect we may consider No. II. as representing the most temperate position, that is to say the best site on which to pitch a camp, thus explaining very satisfactorily the habits of the Campagna shepherds already referred to (page 164).

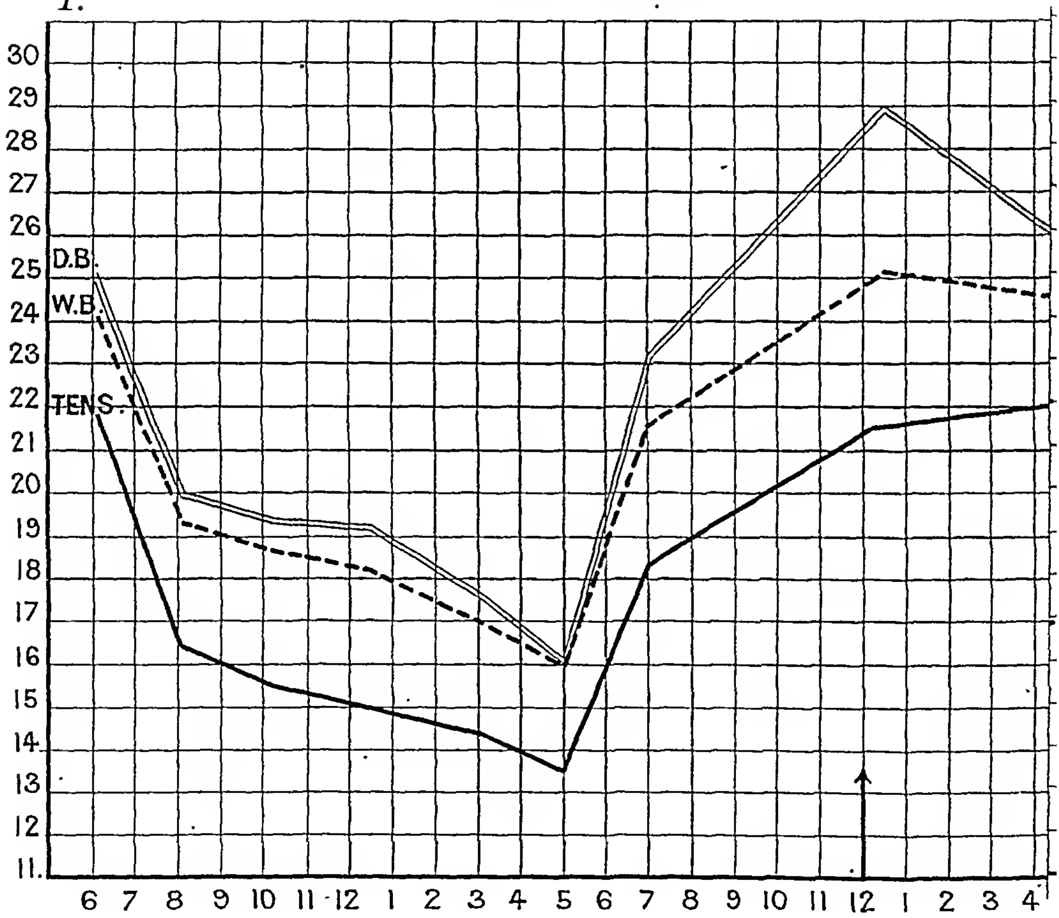
SERIES VII.

TRE FONTANE, AUGUST 19 AND 20, 1885.

ON the morning of August 17th there was a violent thunderstorm accompanied by deluges of rain, lasting nearly four hours, and which travelled over several miles of country. At the time of the previous series of observations, the long continued drought and the intense heat had covered the soil of the Campagna with sun-cracks, some of them large enough to admit the hand easily, many of them so deep that an ordinary walking-stick would not reach the bottom. On traversing the road between the Osteria del Ponticello and Tre Fontane on the morning of August 19th, it was found to have been torn up by the torrents of rain and was for some distance quite impassable for wheeled vehicles. The grass on the edges of the streams in the neighbourhood was all laid; and the soil around covered with mud and rubbish showing the great force and volume of water which had fallen, the quantity being too great to be taken up by the soil with sufficient rapidity. On the Campagna, wherever the grass was at all thin, it had been almost washed out of the ground, and the footpaths with any slope had been converted into temporary watercourses and washed bare of all loose soil. The land in the valley of the Fosso delle Tre Fontane, in the immediate neighbourhood of the Via Laurentina, was covered with sand and mud which had been washed off the road, and irreparable damage had been done to most garden crops; yet, despite this deluge of water, forty-eight hours afterwards there was no trace of it on the high land, which seemed to be as dry and cracked as before, whilst at the foot of the hills and on all the low-lying ground one frequently walked in water. It will appear from this description of the effects of a sudden

I.

On low land near the Osteria.



and violent fall of rain that the drainage from these low hills of volcanic ash and pozzolana is more or less perfect, and that of the valleys between them proportionately defective. On August 19th the heat was almost insupportable, especially on the low ground, where there was a damp suffocating atmosphere exactly resembling that of a tropical plant house. It will thus be seen that the conditions under which the observations of August 19 and 20 were made, were peculiar. On the previous occasion the drought had lasted so long that in all except the most sheltered places and those which, from their natural position, received the little water there was still left to drain from the high land, the soil was literally baked. Between these two sets of observations a deluge of rain fell, the quantity being so great that the cracked and thirsty soil, though probably capable of holding it all, actually retained but a very little. No sooner was the storm over than the heat returned with unabated force with the natural result that the whole country literally steamed and produced an atmosphere of the discomforts of which the inhabitants of the Campagna complained bitterly.

Under these circumstances, then, the series of observations No. VI. was undertaken. The position of the instruments used (numbers I. II. III. VI.) has been already indicated, and it only remains to discuss the results obtained.

TABLE A.

TRE FONTANE. SERIES VII.

Inst. I.—Plate XXV.

Time.	D.B.	W.B.	U.R	Tension.	Remarks.
P.M.					
6.10	25·2	24·2	92	21·84	Cloudless.
8.20	20·0	19·4	94	16·39	
10.15	19·4	18·6	92	15·46	Cloudy to N.W.
A.M.					
12.35	19·2	18·2	90	14·94	
3.5	17·6	17·2	96	14·37	
5.0	16·0	16·0	100	13·54	
7.0	23·2	21·6	86	18·20	Cloudless.
P.M.					
12.30	29·0	25·2	72	21·48	Wind.
5.50	25·2	24·4	93	22·23	

SERIES VII.
Inst. II.—Plate XXV.

Time.	D.B.	W.B.	U.R.	Tension.	Remarks.
P.M.					
6.20	26·5	23·0	73	18·73	
8.30	20·8	19·0	83	15·24	
10.25	19·5	18·2	88	14·75	Gentle breeze.
A.M.					
12.45	18·0	17·0	90	13·81	
3.15	17·5	16·8	93	13·81	
5.12	17·2	17·0	98	14·30	
6.45	23·0	21·0	83	17·27	
P.M.					
12.45	29·0	20·5	43	12·72	
5.30	27·0	22·0	63	16·58	

SERIES VII.
Inst. III.—Plate XXV.

Time.	D.B.	W.B.	U.R.	Tension.	Remarks.
P.M.					
6.30	24·8	22·0	77	17·93	Cloudless.
8.38	22·4	19·8	77	15·58	
10.30	20·8	19·0	83	15·24	Few clouds to N.W.
A.M.					
1.0	19·6	18·4	89	15·02	
3.25	18·8	17·8	90	14·56	
5.20	20·6	19·6	91	16·36	
6.35	22·9	20·6	80	16·64	Cloudless.
P.M.					
1.0	29·0	21·8	50	14·99	Strong wind.
5.20	27·0	22·2	64	16·94	

SERIES VII.
Inst. V.—Plate XXV.

Time.	D.B.	W.B.	U.R.	Tension.	Remarks.
P.M.					
6.38	27·5	24·0	73	20·02	
8.45	22·5	20·5	82	16·71	
10.38	21·0	19·5	86	15·95	Gentle breeze.
A.M.					
1.10	19·5	18·0	86	14·44	
3.38	18·5	17·5	90	14·27	
5.30	20·5	19·5	91	16·16	
6.25	22·5	20·5	82	16·71	
P.M.					
1.10	29·5	24·2	63	19·18	
4.40	29·5	24·5	64	19·77	

SERIES VII.

Inst. VI.—Plate XXV.

Time.	D.B.	W.B.	U.R.	Tension.	Remarks.
P.M.					
6.45	23·5	20·0	71	15·24	
8.55	20·8	18·5	79	14·44	
10.54	19·5	18·0	86	14·44	
A.M.					
1.20	18·0	16·5	85	13·06	
3.50	17·5	16·5	90	13·36	
5.45	19·5	18·5	90	15·24	
6.15	22·5	20·0	78	15·86	
12.0	29·0	21·0	46	13·58	
P.M.					
5.0	27·0	21·0	56	14·81	

TABLE B.

TRE FONTANE.

August 19 *and* 20, 1885.

	Kew.	Tre Fontane.				
		Meadow.	Between vineyards and uncultivated land.	Among eucalypti.	Open Campagna.	Ponte Bultero.
		1.	2.	3.	5.	6.
Mean temperature . .	13·3	21·6	22·0	21·7	23·4	21·9
Maximum temperature .	16·9	29·0	29·0	29·0	29·5	29·0
Minimum temperature .	11·1	16·0	17·2	18·0	18·5	17·5
Excursion of thermometer	5·8	13·0	11·8	10·2	11·0	11·5
Mean hourly variation of temperature	0·63	1·1	1·0	0·82	0·90	0·88
Fall of temperature per hour to minimum . .	0·34	0·83	0·84	0·66	1·0	0·66
Rise of temperature per hour to maximum. .	0·72	1·26	1·57	1·02	1·04	1·43
Mean relative humidity .	69	88·3	79·3	66·7	79·6	75·6
Mean tension of aqueous vapour	7·80	17·6	15·2	15·9	17·0	14·4
Maximum ditto ditto	9·99	22·23	18·73	17·93	20·02	15·24
Minimum ditto ditto	7·13	13·54	13·81	14·56	14·27	13·58
Range of ditto ditto	2·86	9·69	4·92	3·37	5·75	1·66
Mean hourly variation of tension	0·39	0·73	0·73	0·39	0·51	0·38

Examining the data in Table B, we cannot fail to be struck by the practical equality of the maxima recorded by all the

instruments, 29° C. (84·2° F.), and it is to the minima therefore that we must look for such differences as exist. If we place the instruments in order from the lowest minimum to the highest, thus I. II. VI. V. III., we are again reminded of the action of trees in equalising temperature, and the advantages of high and exposed ground as compared with low-lying land in this respect. It may be urged that the largest difference is only 2·8° C. (5·0° F.), but as has been before said, this is by no means the only difference between the records of the various instruments. The mean hourly variation of temperature puts them in the order I. II. V. VI. III., or practically the same as before, the difference between Nos. V. and VI. being only 0·02° C. whilst the difference between Nos. I. and III. is 0·28°C. (0·5° F.). Considering the *ratio* of the rate of fall per hour to the rate of rise we find it to be as follows :—

	1.	2.	3.	5.	6.
1 :	1·5	1·8	1·5	1·0	2·1

Thus the order of the instruments for equability of temperature alone is V. III. I. II. VI., and this although No. III. recorded the slowest rate both of fall and rise ; and while we must credit the trees with contributing materially to this result, we must not lose sight of the fact that on the most exposed site (No. V.) though the mean hourly rate of variation was considerable, it was at the same time practically uniform.

So far temperature ; now let us examine the records of the amount and variation of atmospheric moisture. The order of the instruments as regards mean relative humidity is III. VI. II. V. I. No. III. showing 9% less moisture than No. VI. and 21·6% less than No I. The range of tension shown by No. VI. is very small, but unfortunately the thermometers used were not by any means such sensitive instruments as the others, and though it is probably fair to assume that the variations were not excessive, the results obtained are not strictly comparable with the others. We have therefore again evidence that the conditions prevailing on the site of No. III. among the trees were more equable than in other parts of the estate. The instruments placed in

the valley of the Fosso di Ponte Buttero recorded the same characteristic variations of temperature that have been so often noticed before, the difference between the rate of fall and the rate of rise being particularly noticeable.

We have now to make comparison with the records obtained at Kew.

The mean temperature at Kew was 8·8° C. (15·8° F.) lower than the mean of the five instruments at Tre Fontane; the maximum 12·2° C. (21·9° F.) and the minimum 6·5° C. (11·7° F.) lower than the mean maximum and minimum at Tre Fontane, and the excursion of the thermometer almost exactly one half. The mean hourly variation at Kew was 0·63° C. (1·13° F.), at Tre Fontane 0·92° C. (1·65° F.), the rate of fall per hour at the latter place was just *double* that at Kew and the rate of rise little short of double, though the rate of rise at Kew was almost double the rate of fall. Thus the temperature curve at Kew resembles in form the curves at Tre Fontane differing only in degree; the same applies to the aqueous vapour to a very large extent, the mean relative humidity being somewhat greater than that recorded by instrument No. III. at Tre Fontane, so that generally speaking we may summarise the variations at Kew as being about one half those at Tre Fontane and as occurring about 12° C. (21·6° F.) lower in the scale of temperature.

This series of observations was brought to a somewhat abrupt conclusion, the author discovering, in the course of the afternoon of August 20th. that he was suffering from a very severe attack of ague.

As is usually the case in the Campagna, when heavy rain falls for a short time in the course of a long drought, there was a great increase in the number of cases of fever over the area on which the rain fell, and the author found that numbers of persons who had escaped up to August 16th had fallen ill in the course of the succeeding fortnight. Many of the monks at Tre Fontane were attacked, and this thunderstorm appeared to mark the beginning of the autumnal fever season of the year 1885, which will be remembered as resembling the year 1879 in the number of cases of fever which occurred.

SERIES VIII.

VIGNA DESERTI, SEPTEMBER 11 AND 12, 1885.

THE position and surroundings of the vineyard in which these observations were made will be understood by reference to the map (Plate XXVI.). It stands upon high ground overlooking the valley of the Fosso della' Maranella, three kilometres (about two miles) from the Porta Maggiore, on the Via Prenestina, the road which leads from Rome to Palestrina. This high land, if such it may be called, is about twenty metres (sixty-five feet) above the level of the valley, and is of the usual volcanic structure, tufo of variable quality below, and, as it has been cultivated, a deep layer of somewhat loose and fine soil above. The valley is very damp and boggy and the watercourse ill-regulated, and though towards Rome there are numerous houses, the Casale Deserti is the last on this lonely road for many miles. The neighbourhood has a very evil reputation for unhealthiness, and is sufficiently deserted to permit of the government erecting a large powder-magazine within a short distance (Polv^a del Portonaccio). There is an osteria close to the point where the Fosso passes under the road (see Plate XXVII.) which is shut in summer at about five in the afternoon, those in charge going to Rome to sleep and not returning until six the following morning. No one sleeps in the houses about, during the summer, except the caretakers, who are very frequently changed in order to preserve their health.

The position of the instruments will be readily comprehended by reference to the map and the general view of the locality from the road looking towards Rome (Plate XVII.). They were placed almost exactly along the line of the section

through A, B, No. I. attached to a telegraph pole among young vines, 1·30 metre (4·2 feet) above the soil on ground sloping slightly towards the road, and at such a level that the bulbs of he thermometers were below, and consequently somewhat sheltered by the surrounding land.

No. II. was attached (1·3 metres above the soil) to a post on a large open space behind the house, on ground used for building hay-ricks upon ; the soil was hard, and there was little or no grass upon it, the instrument was well exposed.

No. III. was mounted on the staff within ten paces of the Fosso, on boggy land, 1·3 metre above the soil.

TABLE A.

VIGNA DESERTI. SERIES VIII.

Inst. I.—Plate XXVIII.

Time.	D.B.	W B.	U.R.	Tension.	Remarks.
P.M.					
6.0	22·8	17·5	56	11·64	Cloudy—wind.
6.30	22·4	17·4	58	11·74	
7.17	22·2	17·7	62	12·31	Clear overhead—wind.
8.5	20·0	18·2	83	14·45	
8.45	22·2	18·8	71	14·06	Strong wind—cloudy.
9.40	22·0	19·1	83	15·28	
10.27	22·4	18·1	64	12·83	Clear overhead.
11.6	21·3	18·2	73	13·65	
11.55	21·2	17·7	69	12·92	Wind—few clouds.
A.M.					
12.37	19·5	16·8	76	12·71	Clear and calm.
1.46	19·0	16·2	73	12·00	
3.4	19·5	16·3	70	11·84	Cloudy.
3.56	15·4	14·7	92	12·03	
4.32	16·1	15·0	88	12·03	
4.59	15·8	14·9	90	12·07	Dawn cloudy.
5.18	15·3	14·8	95	12·28	
5.36	14·7	14·2	94	11·77	
5.48	14·8	14·2	93	11·70	
6.33	16·9	15·5	86	12·26	
7.38	18·3	14·9	67	10·55	
8.21	20·2	15·0	54	9·55	
9.28	22·9	17·2	54	11·12	
10.26	24·7	16·2	37	8·53	
11.10	26·1	17·2	36	9·16	
P.M.					
12.45	26·7	16·4	29	7·60	
1.26	28·4	17·6	29	8·38	
2.15	26·4	17·6	37	9·59	
3.1	27·3	18·0	36	9·67	Gale—cloudy.

Series VIII.

Inst. II.—Plate XXVIII.

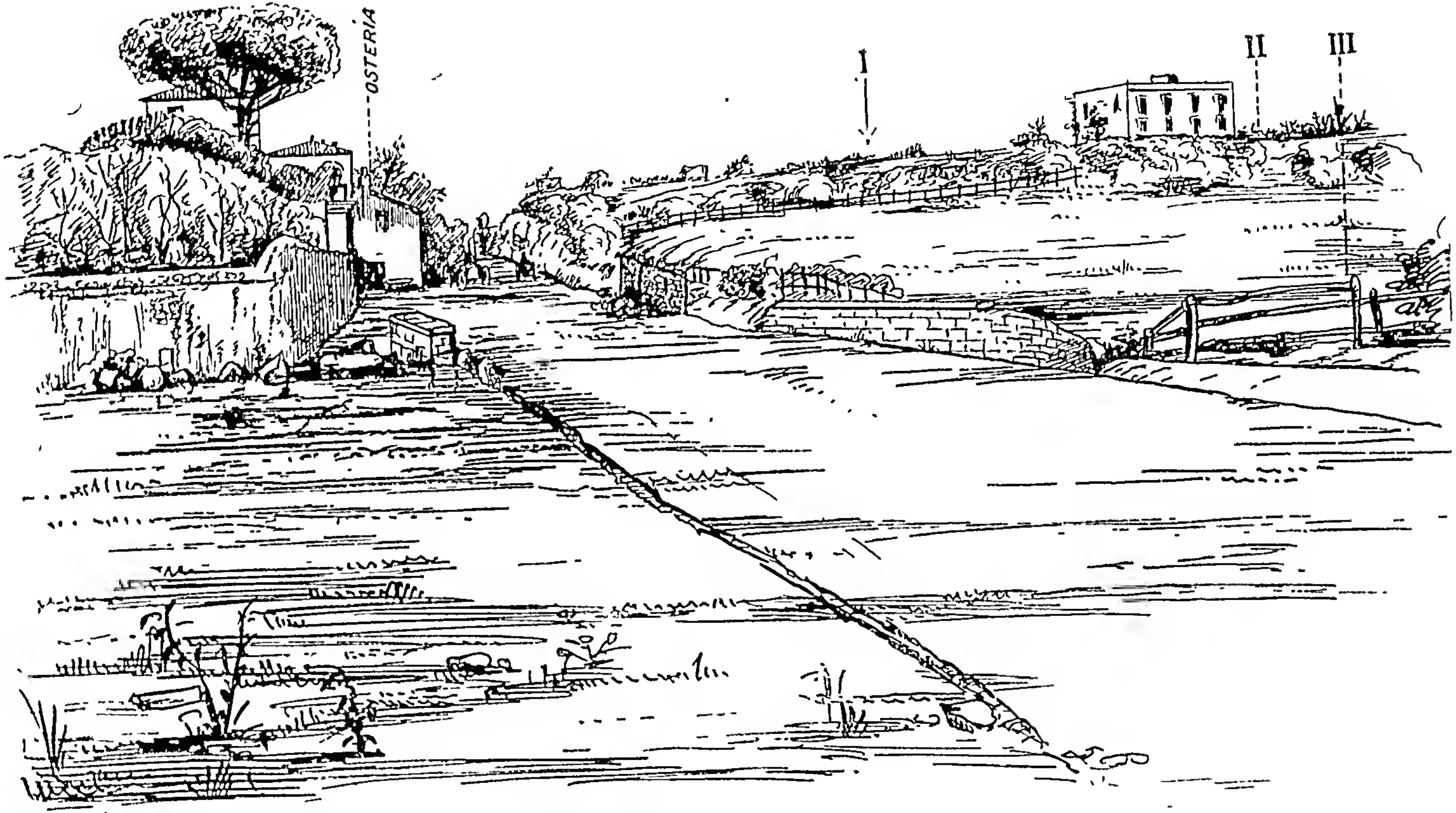
Time.	D.B.	W.B.	U.R.	Tension.	Time.	D.B.	W.B.	U.R.	Tension
P.M.					A.M.				
6.5	22·0	17·0	58	11·37	5.2	15·3	14·2	88	11·39
6.35	21·9	16·9	57	11·28	5.24	14·6	14·6	100	12·38
7.22	21·1	18·0	72	13·46	5.39	14·3	13·5	91	11·04
8.8	21·5	17·6	66	12·59	5.50	14·8	14·0	91	11·42
8.52	21·6	18·2	70	13·47	6.30	16·1	15·0	88	12·03
9.38	21·6	18·5	73	13·95	7.35	19·0	15·0	63	10·26
10.30	22·0	17·6	63	12·28	8.35	21·8	15·9	51	9·85
11·9	22·0	18·0	66	12·91	9.25	23·6	16·7	46	9·94
11.58	20·4	17·0	69	12·34	10.23	25·2	16·5	36	8·66
A.M.					11.18	26·8	16·2	28	7·24
12.40	19·0	15·9	71	11·56	P.M.				
1.49	18·6	15·8	73	11·66	12.40	28·0	17·0	27	7·70
3.8	19·0	15·8	70	11·42	1.40	27·8	16·9	27	7·68
3.59	15·8	14·0	81	10·81	2.26	27·4	18·1	36	9·77
4.35	15·6	14·6	89	11·77	3.7	26·0	17·2	37	9·22

Series VIII.

Inst. III.—Plate XXVIII.

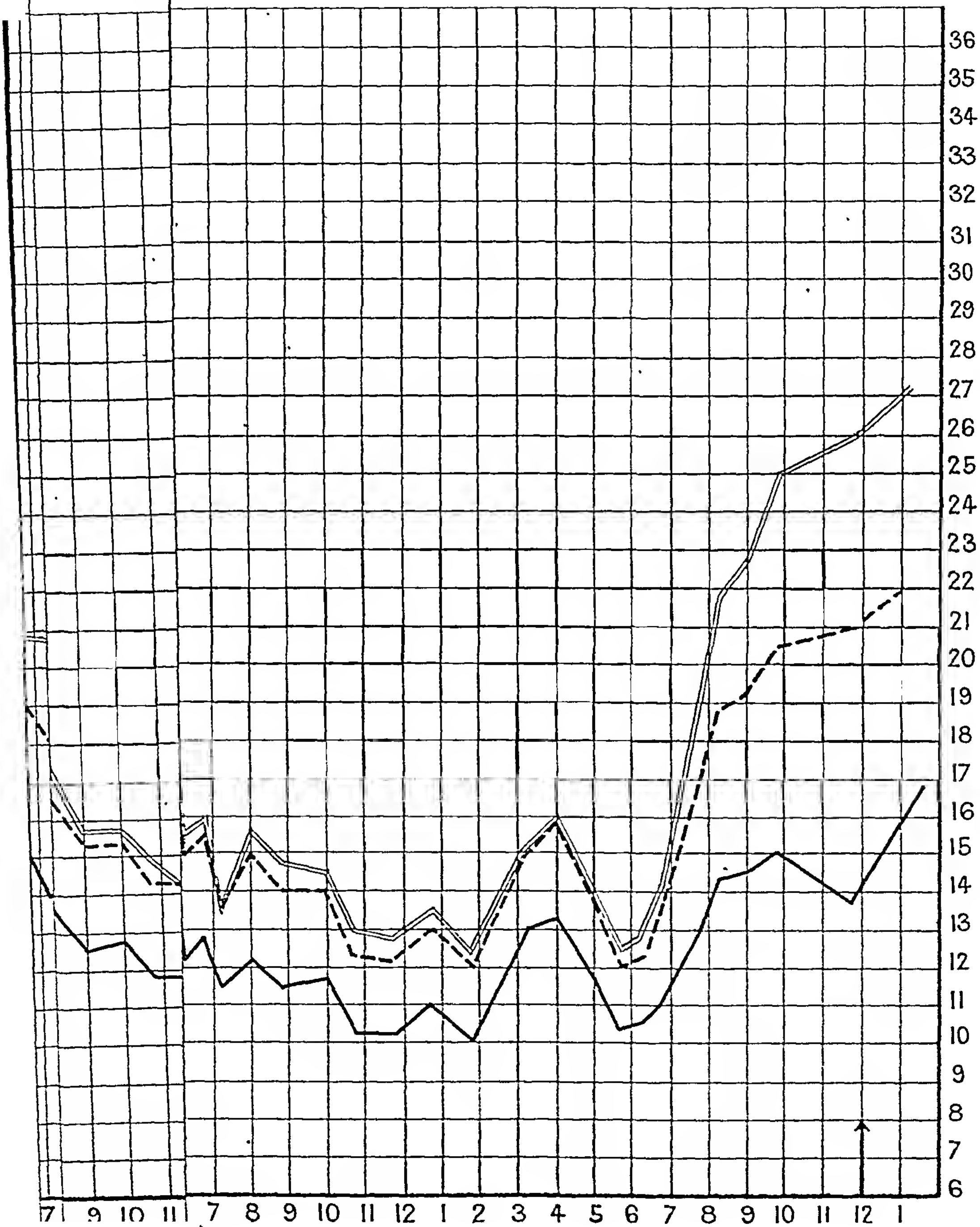
Time.	D.B.	W.B.	U.R.	Tension.	Remarks.
P.M.					
6.10	21·0	19·8	89	16·45	
7.15	20·8	18·2	76	13·96	
8.13	20·6	18·4	80	14·40	
9.32	21·0	19·4	85	15·79	
11.15	21·0	19·4	83	15·45	
A.M.					
12.49	18·2	17·2	90	14·00	
3.15	17·9	16·6	87	13·27	
4.40	15·0	14·2	91	11·58	
5.6	15·0	14·4	93	11·85	
5.31	15·0	14·0	89	11·30	
5.42	14·2	14·0	98	11·79	
5.56	13·4	13·8	100	11·76	Verified.
6.25	14·0	13·4	93	11·09	
7.30	17·7	16·3	86	12·94	
8.30	20·6	17·2	69	12·52	
9·20	22·6	19·0	69	14·14	
10·30	24·0	19·4	62	13·87	
11.23	25·0	20·0	61	14·32	
P.M.					
12.35	27·2	22·2	63	16·82	
1.33	36·8	26·0	—	—	Probably sun.
2.22	25·2	20·4	62	14·88	
3.12	24·4	19·7	62	14·18	

To face page 218.



GENERAL VIEW OF THE VIGNA DESERTI LOOKING TOWARDS ROME.

ttached to a | *r as at S Paolo.*
n's Canal respectively.
1.



VIGNA DESERTI.

September 11 *and* 12, 1885.

	Kew.	Vigna Deserti.		
		1.	2.	3.
Mean temperature	12·3	22·6	20·8	19·7
Maximum temperature	17·1	28·4	28·0	27·2
Minimum temperature	9·1	14·7	14·3	13·4
Excursion of thermometer	8·0	13·7	13·7	13·8
Mean hourly variation of temperature	0·63	1·6	1·3	1·5
Fall of temperature per hour to minimum	0·65	0·70	0·61	0·63
Rise of temperature per hour to maximum	0·53	1·70	1·95	1·97
Mean relative humidity	79	66	63	76
Mean tension of aqueous vapour	8·52	11·56	11·05	13·82
Maximum ditto ditto	10·24	15·28	13·95	16·82
Minimum ditto ditto	6·93	7·60	7·24	11·09
Range of ditto ditto	3·31	7·68	6·71	5·73
Mean hourly variation of tension	0·24	1·05	1·03	1·01

Throughout the whole period of the observations the weather was more or less unsettled, and, though the barometer only varied one or two millimetres, there were constant gusts of wind accompanied by heavy clouds at intervals, though when these had passed all was calm again almost immediately. The full period of twenty-four hours was not completed because the wind rose to a gale about three o'clock in the afternoon of the 12th, and further observation was useless.

Between these observations and the last some three weeks elapsed, and, during this time, rain fell at intervals in sufficient quantity to keep down the temperature and gradually to remove the effects of the long drought. The weather had become more or less unsettled and the barometer, which had hardly varied at all for many weeks, had begun to show signs of disturbance, and at the same time, the fever had increased enormously all over the Campagna.

The figures of Series VIII. show us that with these outward signs of change the characters of the temperature curve of the

Campagna became even more strongly marked; with a diminished mean temperature we have an excursion of the thermometer even greater than in the previous series, 13·7 C. as against 11·5 C., and a mean hourly variation of temperature which shows a considerable increase, 1·46 C. as against 0·95° C. at Tre Fontane. The ratio of the rate of fall per hour to the rate of rise is also notably greater, being for No. I., 1 : 2·42; for No. II., 1 : 3·2; for No. III., 1 : 3·1; or a mean ratio of 1 : 2·9 as against a mean of 1 : 1·58 in the previous series, or but little short of double. The aqueous vapour shows the same characteristics; the mean degree of saturation was less than at Tre Fontane, 66·8 per cent. as against 77·9, but the mean hourly variation of tension was almost double, being 1·03mm. as against 0·55 in the preceding series.

Comparing the records of the instruments one with another—from their relative position they are fairly comparable with Series II. (see page 172)—we find that the differences then observed no longer obtain, and that beyond the fact that on the low ground near the Fosso the temperature was rather less than 3° C. lower, and that the atmosphere contained about 10 per cent. more moisture, there is nothing which points to one site as being markedly different from the others. All we can say is, that the atmosphere behind the house (No. II.) was somewhat drier than in other positions, though as we shall see in the general summary, even this uniformity is not without its significance.

When however we make the comparison with the Kew records, the difference between the two places becomes very evident. The mean temperature at Kew was only **12·3° C. (54·3 F.)** as against a mean of 21·0° C. (69·8° F.) at the Vigna Deserti, the excursion of the thermometer was only about two-thirds as great and the mean hourly variation considerably less than half; the rate of fall per hour to the minimum at Kew was about the same as at the Vigna Deserti, but instead of being as at the latter place only one-third of the rate of rise to the maximum it is actually 10 per cent. greater. The percentage of saturation of the atmosphere with aqueous

vapour at Kew was one-tenth higher than the average of the three instruments at the Vigna Deserti, but the range of tension was barely half and the mean hourly variation little more than one-fifth of that recorded at the latter place, so that the differences between the temperature curves of the two localities are even more accentuated than in the previous cases.

SERIES IX.

ISOLA SACRA, SEPTEMBER 18 AND 19, 1885.

THE ninth and last series of observations was made on the Isola Sacra at the mouth of the Tiber. The locality was chosen for two reasons: firstly, because it was considered desirable to examine the meteorological conditions of a site not far removed from the sea; and secondly, because the neighbouring village of Fiumicino had sent to the Roman hospitals, in the week preceding the observations, more cases of pernicious malarial infection than the whole of the rest of the Campagna in the preceding year.

The whole of the land which lies between Trajan's canal and the Tiber is exceedingly low, barely reaching one metre above sea-level and much of it less than one metre; it is entirely composed of alluvium brought down by the Tiber, and the soil is for the most part wet and the drainage very defective, if it can be said to exist at all.

For a considerable distance in both directions from the angle formed by the junction of Trajan's canal with the river a high embankment has been constructed for the purpose of protecting this portion of the Isola from inundation; but the soakage from the river and canal appears to be very considerable, and the swarms of small green frogs which inhabited this corner of the area at the time of the observations afforded additional proof of the dampness of the locality.

Trajan's canal makes with the main stream what for purposes of description may be called a right angle, and, from the angle, and parallel to the right bank of the Tiber, a small mole has been constructed in order to prevent the breaking down of this angle of the island by the water, this mole is about sixty metres in length. For the purpose of these observations four instruments were used, placed as follows:

No. I. About twenty-five metres from the extremity of the mole and 1·10 metre above the soil.

No. II. Attached to the trunk of a dead tree at the same height above the ground and close to the canal.

Nos. III. and IV. Attached to the staff in the same vertical line, fifty paces from the bank of either stream No. II., 2·0. metres and No. IV. 1·0 metre above the grass.

TABLE A.

ISOLA SACRA. SERIES IX.

Inst. No. I.—Plate XXVIII.

Time.	D.B.	W.B.	Tension.	U.R.	Remarks.
P.M.					
3·0	26·4	20·4	14·15	55	
3.47	25·9	20·7	14·97	60	
4.17	25·4	20·8	15·45	64	
4.33	25·1	21·0	15·97	67	
4.48	24·6	20·7	15·77	68	
5.5	24·2	20·8	16·18	72	
5.25	23·4	20·5	16·16	75	
6.6	20·0	18·7	15·25	88	Slight mist on surface of ground.
6.23	20·1	18·0	14·07	80	Grass wet—covers of instruments changed.
6.54	19·4	18·1	14·66	87	
7.23	17·0	16·4	13·52	94	Very heavy dew—very calm.
8.13	16·5	15·8	12·94	93	
9.0	15·7	15·2	12·56	95	Slight breeze.
10.0	15·6	15·3	12·76	97	Fog returned.
10.58	14·7	14·2	11·76	94	
11·52	14·3	13·8	11·45	94	Cold.
A.M.					
12.58	14·1	13·5	11·16	93	
2.0	13·1	13·1	11·23	100	Breeze.
3.15	15·8	15·4	12·79	96	Cloudy--scirocco--dense wet fog.
4.14	15·8	15·4	12·79	96	
5.11	14·5	14·2	11·88	97	Fog—wind E.
6.0	14·4	12·9	10·18	83	Fog disappeared.
6.22	14·3	13·2	10·64	88	
6.52	15·2	13·8	10·91	85	Wind S.W.
7.55	18·6	16·8	13·14	82	Clear.
8.29	21·4	19·4	15·53	82	
9.5	23·0	19·4	14·55	70	
10.0	24·8	20·0	14·44	62	

TABLE A.

Isola Sacra. Series IX.

Inst. II.—Plate XXVIII.

Time.	D.B.	W.B.	Tension.	U.R.	Remarks.
P.M.					
4.24	25·2	22·2	17·87	74	
4.53	23·6	21·7	18·14	84	
5.14	22·8	21·4	18·09	88	
6.3	20·6	19·9	16·85	94	Slight mist on surface of ground.
6.20	20·2	19·3	16·11	91	
6.49	19·3	18·9	16·00	96	Grass wet—covers of instruments changed at sunset.
7.20	18·3	18·1	15·33	98	Heavy dew—very calm.
8.9	17·6	16·8	13·75	92	
8.58	15·7	15·3	12·50	96	Slight breeze—fog returning.
9.52	15·7	15·4	12·85	97	
10.43	14·8	14·4	11·97	96	
11.49	14·1	14·1	11·99	100	Cold.
A.M.					
12.55	14·5	13·8	11·33	92	
3.12	16·4	15·8	13·00	94	Cloudy-scirocco-dense wet fog.
4.11	16·2	16·1	13·56	99	
5.8	14·8	14·8	12·54	100	Fog—wind E.
5.55	13·4	13·4	11·46	100	Fog disappeared.
6.17	13·6	13·3	11·20	97	
6.49	15·0	14·6	12·14	96	Wind S.W.
7.52	18·5	17·4	14·12	89	Clear.
8.26	21·1	19·6	16·06	86	
9.2	22·6	20·8	17·17	84	
9.58	23·0	20·8	16·92	81	
11.46	25·0	22·1	16·83	76	

TABLE A.

Isola Sacra. Series IX.

Inst. III.—Plate XXVIII.

Time.	D.B.	W.B.	Tension.	U.R.	Remarks.
P.M.					
4.0	24·9	20·5	15·24	65	
4.27	24·2	21·2	16·88	75	
4.56	23·8	21·2	17·13	78	
5.17	23·2	21·0	17·14	81	
6.0	20·8	20·2	17·24	94	Slight mist on surface of ground.
6.17	19·4	19·0	16·10	96	Grass wet—covers of instruments changed at sunset.
6.44	18·0	17·9	15·20	99	
7.13	18·0	17·9	15·20	99	Heavy dew—very calm.
8.0	16·6	16·0	13·17	99	
8.52	15·4	15·0	12·46	96	
9.52	15·4	14·9	12·31	95	Light breeze—fog returned.
10.48	13·4	13·4	11·46	100	
11.44	13·2	13·2	11·15	100	Cold.
A.M					
12.48	13·9	13·4	11·15	94	
1.52	12·8	12·6	10·76	98	Breeze.
3.6	15·6	15·2	12·42	96	Cloudy--scirocco--dense wet fog.
4.6	16·2	15·8	13·13	96	
5.5	14·6	14·6	12·28	100	Fog—wind E.
5.40	13·2	13·0	11·04	98	Fog disappeared.
6.13	13·2	12·8	10·78	95	
6.46	14·2	13·5	11·10	92	Wind S.W.
7.50	18·0	16·7	13·36	81	Clear.
8.23	20·2	18·3	14·49	82	
8.58	22·0	19·5	15·32	78	
9.54	24·0	20·7	16·14	73	
11.50	24·7	20·4	15·19	66	
P.M.					
1.11	23·6	22·2	19·04	88	

TABLE A.

ISOLA SACRA. SERIES IX.

Inst. IV.—Plate XXVIII.

Time.	D.B.	W.B.	Tension.	U.R.	Remarks.
P.M.					
4.0	26·1	20·8	15·02	60	
4.27	26·1	21·0	15·97	67	
4.56	24·4	20·6	15·72	69	
5.17	23·0	20·0	15·55	74	
6.0	18·5	17·5	14·27	90	Slight mist on surface of *ground.*
6.17	15·5	15·0	12·39	95	Grass wet—covers of instruments changed at sunset.
6.44	16·0	15·5	12·80	95	
7.13	13·5	13·5	11·53	100	Heavy dew—very calm.
8.0	15·6	15·0	12·33	93	
8.52	14·8	14·1	11·56	92	
9.52	14·5	14·1	11·74	95	Light breeze—fog returned.
10.48	13·0	12·4	10·37	93	
11.44	12·8	12·3	10·36	94	Cold.
A.M.					
12.48	13·5	13·2	11·13	97	
1.52	12·4	12·0	10·21	95	Breeze.
3.6	15·2	15·0	12·58	98	Cloudy-scirocco-dense wet fog.
4.6	16·0	15·8	13·25	98	
5.5	14·2	14·0	11·79	98	Fog—wind E.
5.40	12·5	12·2	10·41	96	Fog disappeared.
6.13	12·8	12·4	10·49	95	
6.46	14·2	13·5	11·10	92	Wind S.W.
7.50	19·4	17·0	12·95	77	Clear.
8.23	21·9	18·9	14·41	74	
8.58	22·8	19·3	14·50	70	
9.54	25·0	20·5	15·18	64	
11.50	26·1	20·1	13·82	55	
P.M.					
1.11	27·2	22·2	16·82	63	

ISOLA SACRA.

September 18 *and* 19, 1885.

	Kew.	Isola Sacra.			
		On the mole.	On canal bank.	On staff, fifty paces from banks.	
		1.	2.	3.	4.
Mean temperature	11·5	19·0	18·4	18·2	18·0
Maximum temperature . . .	16·7	26·4	25·5	24·9	27·2
Minimum temperature . . .	7·7	13·1	13·4	12·8	12·4
Excursion of thermometer . .	9·0	13·3	12·1	12·1	14·8
Mean hourly variation of temperature	0·67	1·6	1·6	1·6	2·1
Fall of temperature per hour to minimum	0·70	1·2	1·0	1·2	1·3
Rise of temperature per hour to maximum	0·76	1·5	1·9	1·19	1·34
Mean relative humidity . . .	89	75	91	89	84
Mean tension of aqueous vapour	9·02	13·44	14·54	13·96	12·89
Maximum ditto ditto . .	10·57	16·18	18·14	19·04	16·82
Minimum ditto ditto . .	7·61	10·18	11·20	10·76	10·21
Range of ditto ditto . .	2·96	6·00	6·94	8·28	6·61
Mean hourly variation of tension	0·32	1·03	0·99	1·18	1·48

At the beginning of the observations the weather was clear and warm, and very pleasant; the Alban hills were enveloped in heat haze and were occasionally concealed from view; details as to the changes which took place will be found in Table A, under the heading "remarks."

Again we have to notice the decline in the mean temperature 18·4° C. (65·1° F.) as compared with that recorded in the last series, though in making the comparison something must be allowed for difference of situation. It is generally supposed that inland stations are more liable to excessive variations of temperature than stations on the coast, and there can be no doubt that such is generally the case; in this instance however it is worthy of note that the excursion of the thermometers was but little less than at the Vigna Deserti, more than twenty miles from the sea in a direct line, and if we take the lower mean temperature on the Isola Sacra into consideration, we may possibly consider the slight difference as of no account, for the lower the mean temperature within certain limits, the less is the excursion of the thermometer.

The mean hourly variation of temperature on the Isola was also high, and, except in the case of instrument No. II., there is no very striking difference between the rate of rise and the rate of fall; in this respect the curves differ from those obtained in the previous observations. The mean relative humidity was high, but this was to be expected from the situation; the fact that all the instruments at one time or another during the period of observation recorded complete saturation of the atmosphere is not surprising, nor do the data as to the general variations of the aqueous vapour call for any particular remark. Comparing the instruments one with another; No. I. on the mole showed the highest, and Nos. II. III. and IV. a progressive diminution of mean temperature, the last named having the greatest range and the greatest mean hourly variation. The difference between the rate of rise per hour and the rate of fall is greatest in No. II. and least in Nos. III. and IV., in which, though there is a difference of a tenth of a degree in the rate, the ratio is practically unity, whereas in No. II. the rise was nearly twice as rapid as the fall. Considering that the greatest distance between any of the instruments was less than 80 metres ($87\frac{1}{2}$ yards), we have here an instructive example of important differences of meteorological condition within an exceedingly small area. The difference of the excursion of the two thermometers on the staff is noteworthy, 2·7° C. (4·8° F.), the lower one registering the higher maximum, the reverse of what was found to occur at San Paolo (pp. 175 and 176).

The relations of the aqueous vapour call for no special remark, excepting only the curious irregularity of the instruments in the times at which they recorded complete saturation. This was noticed at the time of the observations and many of them were at once repeated, under the impression that a mistake had been made, but as the author had on this occasion and at the Vigna Deserti, the assistance of a friend engaged in somewhat similar observations, and each read the other's instruments as well as his own and kept an independent record, it is practically impossible that there should have been any mistake in the readings. If, for example, we compare

instruments Nos. I. and II. between the hours of 2 a.m. and 6 a.m., we find the percentage of saturation recorded by No. I. gradually diminished, whilst in the same period No. II. showed a steady increase up to complete saturation, which was maintained for at least an hour; again at 7·13 p.m. No. I. was progressing from 87 to 94 per cent. whilst No. IV. showed complete saturation.

Though separated from one another by a difference of level of only one metre Nos. III. and IV. exhibited, between the hours of 6 p.m. and midnight a somewhat remarkable difference in the degree of saturation recorded; during this period No. III. showed a mean of 97 per cent whilst No. IV. showed only 94 per cent. The explanation of these differences is perhaps to be found in the movements of the mist which appeared about sunset and, with several intermissions, hung about until dawn; at times its behaviour was very peculiar, rising slowly from the ground to about the height of a man's waist, and after remaining stationary for a time lifting itself as slowly to the height of several feet leaving the air clear below with a layer of fog over-head which dispersed slowly or quickly according as there was any wind or no: sometimes it would descend again before dispersing, but its limits generally remained sharply defined. At about 3 a.m. the whole neighbourhood was enveloped in a fog so dense that it required extreme caution in visiting the instruments in order to avoid falling into the river.

Not far from the angle of the Isola in which the observations were made a quantity of trenching tools and appliances had been deposited in preparation for drainage works, since completed; a large hut had been erected for the storage of these tools, and a man left in charge who occupied a part of it informed the author that these peculiar fogs occurred every night in summer and autumn and that "they were the cause of the fever"; his method of protecting himself, was to make a large fire soon after sundown and having warmed his hut thoroughly, to remain in it all through the night. At 3 a.m. the temperature inside this hut was 21·5° C. (70·7 F.) and the atmosphere contained about 58 per cent. of possible moisture;

outside, the thermometer stood at about 15° C. (58° F.), the atmosphere was almost saturated and as uncomfortable as it well could be.

In consequence of the great difference of situation, comparison between the Isola Sacra and Kew is perhaps hardly justifiable, nevertheless there are some points worthy of notice. The mean hourly variation of temperature at Kew was small and very regular, on the Isola Sacra, though regular it was considerable, 1·7° C. as against 0·67° C. at Kew. For the temperature, the atmospheric moisture at Kew was as great or even greater than on the Tiber, but the mean hourly variations were very small indeed in comparison. The maximum temperature at Kew was low, 16·7° C. (62° F.), and would be regarded by most persons as distinctly cold, whereas on the Isola Sacra it averaged 26° C. (78·8° F.), so that during a considerable portion of the day the weather might be described as hot, the temperature falling after sundown at the rate of more than one degree Centigrade per hour, the accompanying wet fog enormously increasing the sense of change.

CHAPTER XIV.

GENERAL SUMMARY OF THE RESULTS OF OBSERVATIONS ON TEMPERATURE AND ATMOSPHERIC MOISTURE.

THE observations the results of which have been detailed were made in order to determine what, if any, is the relationship existing between local meteorological conditions and the local distribution of malaria, and incidentally to discover in what respects a malarious differs from a non-malarious climate. We have now to consider to what extent the data obtained enable us to give a definite answer to these questions.

The line of argument which we have adopted in considering the relation of local meteorology to malaria is simple. The inhabitants of the Campagna in the mode of construction of their houses, in the choice of sites for them, and in their manner of conducting themselves when compelled to pass the night in the open, have been shown to take cognisance of apparently insignificant differences of level and general situation; these, and such other precautions as they may take, have for their declared object the protection of the individual from fever. We have investigated the meteorological conditions prevailing in certain localities, which presented varying degrees of unhealthiness, and we have learned :— 1. That the range of temperature during the twenty-four hours in the Campagna is very great, and that the rate of change is excessive, especially about sunset and sunrise. 2. That these changes are greatest and most pronounced on the low ground, and that a very insignificant alteration of level produces a very marked change in the character of the temperature curve. 3. That

at an elevation of less than two metres above the soil, the mean temperature is distinctly higher, and the degree of saturation of the atmosphere with aqueous vapour distinctly lower, than on or near the ground. 4. That if comparison be made between the variations of temperature during twenty-four hours observed upon a hill and on a building respectively, each of which rises to the same height from a given datum line, it will be found that the temperature on the building is more equable than on the hill. 5. That the variation of temperature and atmospheric moisture may be very considerable within a very limited area. Applying these data to the habits of the people we are more or less justified in assuming,

A. That the dread of exposure at sunset and sunrise and the supposed risk incurred by such exposure, probably arise from the discomfort caused by the violent changes of temperature which occur at those times.

B. That the choice of elevated sites for the erection of houses, and more especially the building of houses on tombs, is rational, inasmuch as it has been shown that a more equable climate is thereby secured.

C. The habits of the shepherds in preferring high ground and in raising their beds considerably above the soil, though based upon a belief, or possibly experience, that thereby they run less risk of acquiring fever, are justified by the results of observations which show that, whether they escape the fever or no, they at least secure themselves to some extent against excessive changes of temperature and atmospheric moisture.

The observations at Tre Fontane, whilst confirming these results generally, show further the influence of trees in equalising climate, and the great differences which may exist over very limited areas. Those on the Vigna Deserti afford further proof of the existence of these local differences, and show the value of a slightly elevated situation as compared with a valley; the observations on the Isola Sacra still further prove the possibility of great variations occurring within a very small area, in both a horizontal and vertical direction.

Taking all these facts into consideration, we are justified in

saying that the practices of the inhabitants of the Campagna, though nominally dictated by a desire to avoid fever, practically result in the avoidance of extremes of temperature and atmospheric moisture. Were the protection afforded by the precautions taken in any sense absolute, we should have some reason for believing that these climatic changes stood to the fever in the relation of cause and effect; and though we cannot fairly make this deduction, we are compelled to argue a very close connexion between the two. In any case we may claim to have proved that what we found to be true of continents, individual countries, and provinces of those countries, is equally true of exceedingly small areas.

Thus, no matter under what conditions we study the disease, we cannot separate it from climate, and more especially from extremes of temperature and humidity. This may be a mere coincidence, and admitting, as we must admit, the existence of this relationship, in the Roman Campagna at all events, we can only formulate the question under consideration as we have before—Are these conditions in themselves sufficient to produce the disease, or, do they simply favour the growth of a pathogenic organism? The actual consideration of this question must be deferred until we have the whole of the evidence as to the possible existence of such an organism before us, but it will be well here to indicate the general significance of these climatic variations and their possible bearing on the etiology of malarial fever.

A fall of temperature of a certain number of degrees is to the meteorologist the result of certain atmospheric phenomena, and nothing more; to the physiologist these phenomena are in themselves of the very greatest importance, though they are not perhaps accorded the consideration which they deserve. We are accustomed to say that it is cold or hot, damp or dry, and to act upon our sensations without considering why, or whether the means we adopt to meet these conditions are the best. With the thermometer at 4·5 C. (40° F.) and a damp atmosphere, the sensation of cold, in the general acceptation of the term, is far more acute and uncomfortable than a temperature of −5·5 C. (22° F.) with a dry atmosphere, showing

how great is the influence of atmospheric moisture on our sensations. In the same way, a dry heat is far more tolerable than the same temperature when the air is loaded with moisture. Our bodies are not thermometers, and our sensations of cold and heat, instead of affording a criterion of the actual temperature, are the worst possible guides, for they represent only the total result of the action of a number of complex conditions upon a still more complex organism; they are in fact purely relative, though, as we shall see in a later chapter, they may to some extent be taken as an index of the activity of certain physiological processes going on in our bodies, and which, though little understood, are of very great importance. Without concerning ourselves at present with the reason why, it is worthy of remark that, though the actual temperature may vary somewhat with different individuals, there *is* a temperature which most persons will agree to pronounce hot, and assuming the air to be tolerably dry, this temperature in England may be said to be a little more than 22° C. (71°·7 F.), and if the thermometer rise to 29° C. (84°·3 F.) complaints as to the intolerable heat will be more or less general, though if it endure for a time these will cease, in other words we become accustomed to it. But if we go to the other end of the scale we find that if the air be dry, there is no such general consensus of opinion as to the degree of cold and a fall of six or eight degrees centigrade will be tolerated without much complaint. It is even possible, if the change be from a few degrees above freezing point with a damp atmosphere, to find many persons who will say that it feels warmer, though the thermometer have *fallen* to as many degrees below; what has really happened is that the moisture has been precipitated from the atmosphere, as a result the overcoats and wraps which were necessary with the higher temperature become a burden, although, as registered by the thermometer, it is several degrees colder.

Bearing these facts in mind, we can understand why the excursion of the thermometer in the Campagna should produce a greater sense of change than at Kew; not only does the temperature fall very considerably below our supposed

neutral point, but it also rises very much above it, and the fall is accentuated by the almost complete saturation of the air with aqueous vapour at the lower limit, whereas at Kew, the neutral point is very rarely passed, and when this is the case, the rise is not often sudden, nor is the fall so great as in the Campagna, and in no case does the rate of change at Kew approach that of the Campagna. Nor are these the only points of difference between the two places; the quantitative analysis of the data shows that the exchange of heat in the Campagna is vastly greater than at Kew; the atmosphere almost invariably contained a higher percentage of aqueous vapour, and the mean temperature being higher, a much larger quantity per unit of volume. The radiation in the Campagna is incomparably greater than in England, and the sense of cold at night is enormously increased by the precipitation of this excessive amount of aqueous vapour as dew. These differences have a very practical effect. In England, to bivouac in the open in summer, in fine weather, is pleasant, even without a fire, and would rarely produce any bad effect upon a healthy individual; to do so in the Campagna would be little short of madness.

So far as the author has been able to observe, these constitute the characteristic differences between the two localities; something now requires to be said as to the local differences which have been shown to occur in the Campagna and their bearing on our subject. The second series of observations at San Paolo affords us the most typical example (p. 175). From the records of the instruments the limits of difference appear small and of no practical importance, and it might well be asked, Is it possible that a difference of 4°·3 C. (7°·7 F.) in the range of temperature, of about 12 per cent. in the mean relative humidity, with a slower rate of change of temperature, can be of consequence? To this it can only be answered that, judged by mere sensations, these differences *are* of very great consequence (pp. 177–78). It is worthy of remark that the excursion of the instrument No. IV. was confined to a portion of the scale above the limit which we have said most persons would consider warm, whilst the other instruments not only

recorded a temperature below this limit, but this low temperature lasted for several hours.

Small though the differences in the aqueous vapour may appear, experience teaches us that they produce relatively great effects on those exposed to them, and the fact that the habits of the *contadini* are so perfectly parallel with these variations of temperature and atmospheric moisture, is a further proof of how sensible the human organism is to changes which, regarded arithmetically, appear insignificant; nor can there be any reasonable doubt that in following these instincts, if instincts they may be called, they either escape the fever or at least protect themselves to a very considerable extent.

The connection is become so close between these climatic changes and the disease that, though we may not be altogether justified in assuming that they stand to one another in the relation of cause and effect, we are equally precluded from rejecting them as a possible explanation of the phenomena of malarial fevers.

CHAPTER XV.

RELATION OF MALARIA TO POPULATION AND TO THE CONDITION OF THE PEOPLE.

WE have examined the relation of malaria to altitude, to the conformation and constitution of the soil, to cultivation, water, and general meteorology; it only remains to consider the effect of population and the condition of the people, on the distribution of the disease.

Among the many peculiarities of malaria, its attachment to localities is perhaps the most remarkable. Whatever the precise conditions may be which give rise to the disease, it is a well-ascertained fact that they are present in a more or less inverse ratio to the density of the population, and are perhaps most intense in some of the uninhabited parts of the earth. The disease, so far as our present knowledge enables us to judge, is neither infectious nor contagious, and in order to acquire it the individual must go himself to the fountain-head and expose himself to the requisite conditions.

In its relation to population, there is a very close analogy between malaria and the animals or reptiles dangerous to man of a newly explored country. Like these it gives way before the advance of population and civilization. The pioneers suffer, and sometimes so severely that the attempt has to be abandoned; but once a footing gained, the malaria slowly diminishes in intensity around the inhabited and cultivated areas, until, when hamlets have become towns, and towns great cities, it is difficult to imagine that there ever was

a time when it was almost impossible to live upon their sites.

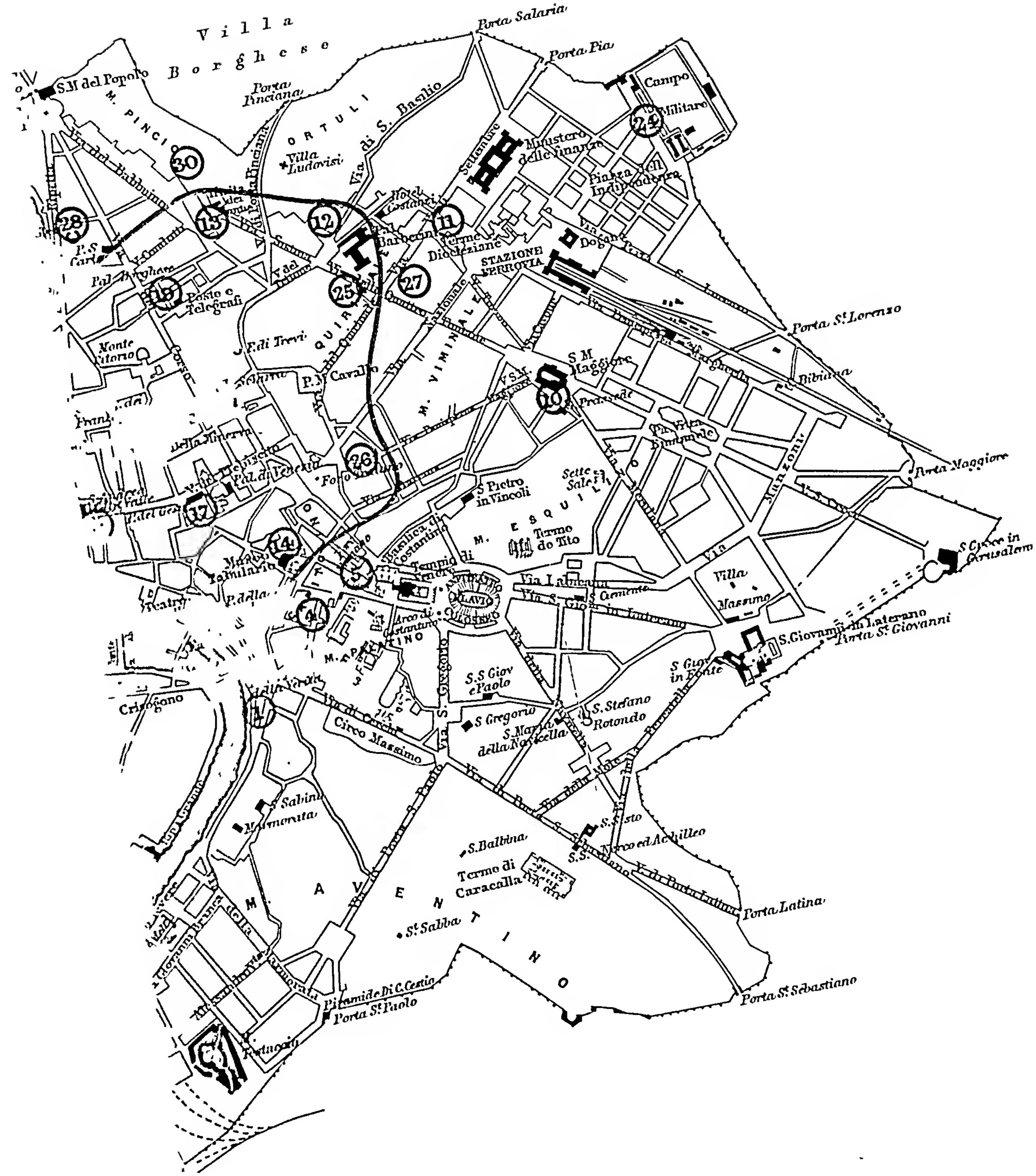
The history of the cities of the United States is to a very large extent the history of the slow but steady disappearance of malaria before advancing population. The process has even begun in Africa; and though the results are as yet utterly insignificant, when we consider what has still to be accomplished, there is every reason for believing that, in the course of time, the terrible fevers of that continent will be mitigated, if not altogether extinguished, by the progress of civilization and the works which follow in its track.

We are, however, concerned more especially with the province of Rome. We have seen, in tracing the history of the disease within it, that the population did not diminish and gradually disappear because of the malaria, but that the malaria followed upon the decline of the population from political causes, and that as population and cultivation diminished so did the malaria increase. The struggle in tropical countries is of necessity much harder, and the disease may prove, and sometimes has proved, too strong for its opponents; still, there can be no doubt of the general truth of the statement that the denser the population the less the intensity of the malaria. The city of Rome itself affords, perhaps, the most perfect proof of this.

Giov. Batt. Doni,* in the year 1666, clearly recognized variations in the intensity of the disease in different quarters of the city, estimating the healthiness of a given district by:—
1. Exposure to the N. and E.; 2. Distance from the Tiber; 3. Altitude; 4. Density of population.

On this basis he finds the most unhealthy parts to be the Velabrum and the Forum, whilst the summits of the Janiculum and Esquiline hills are considered by him to be more healthy than the region of the Campo Marzio, in spite of the greater density of the population in the latter. Felix Jacquot (*Lettres Médicales sur l'Italie*) in 1850 confirms the general conclusions

* Jo. Baptistae Donii, Patricii Florentini, *De Restituenda Salubritate Agri Romani.* Opus posthumum. Florentiae MDCLXVII. pp. 8–12.


Villa Borghese
S.M. del Popolo
M. Pincio
Porta Pinciana
Porta Salaria
Porta Pia
Ortuli
Villa Ludovisi
Via di S. Basilio
Campo Militare
Ministero delle Finanze
Piazza dell Indipendenza
Terme Diocleziane
Stazione Ferrovia
Dogana
Porta S.t Lorenzo
Posta e Telegrafi
Monte Citorio
F. di Trevi
Quirinale
P. M. Cavallo
M. Viminale
S M. Maggiore
Prassede
Bibiana
Pa. Vitt. Emmanuele
Porta Maggiore
Manzoni
Foro Traiano
Pal. di Venezia
della Minerva
S. Pietro in Vincoli
Sette Sale
M. Esquilino
Terme di Tito
Basilica di Costantino
Tempio di Venere
Via Labicana
Colosseo
Arco di Costantino
Via S. Giov. in Laterano
S. Clemente
Villa Massimo
S. Croce in Gerusalemme
S. Giovanni in Laterano
Porta S.t Giovanni
S. Giov. in Fonte
M. Palatino
S. Gregorio
S.S Giov. e Paolo
S. Stefano Rotondo
S. Maria della Navicella
Circo Massimo
Crisogono
S. Sabina
Marmorata
S. Balbina
Terme di Caracalla
S.S. Nereo ed Achilleo
S. Sisto
Porta Latina
M. Aventino
S.t Sabba
Piramide di C. Cestio
Porta S.t Paolo
Porta S.t Sebastiano
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of Doni, and divides the city into three zones: a central, in which the malaria presents a minimum; a peripheral, in which it reaches a maximum; and a middle zone, in which it is of intermediate intensity.

Colin (*Traité des Fièvres Intermittentes*, Paris, 1870, p. 94) gives an example of the extreme difference between the central and peripheral portion of the city in this respect. In the year 1864, on August 20th, two battalions of the same regiment, numerically equal, had respectively 137 and six men in hospital from fever. The battalion which was most stricken furnished the guards for one of the outlying parts of the city; the other was quartered in the convent of the Gesù in its very centre.* The same author has constructed a malaria map of the city from the returns of the troops quartered in the twenty-four casernes distributed over it during the years 1864-5.

This is particularly valuable, for the data are obtained from individuals of about the same age, having the same diet, and similar duties, differing only in their place of habitation. This map (Plate XXIX.) displays beyond all doubt the fact that the disease increases in intensity from the centre, near the Pantheon, to the periphery.

During the occupation of the city of Rome by the French, some of the most unhealthy quarters greatly improved as the result of a sudden increase of population. For example, the neighbourhood of the Baths of Diocletian after the building of the railway station; the Borgo, which, so long as the Popes abandoned the Vatican in summer, was but thinly populated, greatly improved when, after Leo XII. set the example of living there almost all the year round, population flocked to it. Bailly (*Traité des Fièvres Intermittentes*, Paris, 1825, p. 127) describes the Borgo as being most unhealthy, and now, though not by any means free from the imputation of being malarious, it is comparatively healthy.

Ten years after Colin, Lanzi and Terrigi (1877) constructed

* In the year 1811, eighty men of the regiment of La Tour d'Auvergne, placed by necessity in a barrack outside the Porta del Popolo, yielded in three weeks fifty-one cases of fever, of which number twenty-seven died.

a similar map of Rome[1] (Plate XXX.) which tells the same story of the progressive diminution of malaria with the increase of population and inhabited houses. The present distribution of the disease within the city exhibits a still further diminution of the infected area (Plate XXXI.) in exact proportion to the extent of the buildings erected since 1874.

We may therefore regard it as proven that malaria is incompatible with a dense population. The fact is by no means new, but on the contrary has been recognized from the earliest times, and the attempts to establish inhabited centres and *domuscultæ* in the Campagna which we have recorded are proof of the importance attached to it nearly a thousand years ago.

In this connexion we cannot pass over the superstition, for there is no other word which so well expresses it, that the Ghetto, or Jews' quarter, is the healthiest part of Rome. That there is *less malaria* in the Ghetto than in other parts of the city may be, and probably is, true, and in this sense, and this sense only, is the statement correct. It is a fact that though close to the Salara and on the confines of one of the most fever-stricken parts of Rome within the walls, malaria is all but unknown among its inhabitants, *i.e.*, those whose occupation does not take them into the Campagna, and it is by far the most densely populated parish in Rome. The average number of inhabitants to each 10,000 square metres built upon, for the whole city, is 105·39, the Ghetto, or Claustro Israelitico as it is known in the municipal books, has a population of 315·20 for the same area, or just three times the average of the whole city. The next most densely populated parish is that of S. Lucia del Gonfalone,[2] with 220·44, inhabitants per

[1] The numbers on the map of Rome after Lanzi and Terrigi (Plate XXX.) indicate the following springs: 1. S. Maria delle Grazie; 2. A. Lancisiana; 3. Antico Orto Botanico; 4. A. Corsiniana; 5. A. delle Mole Gianicolensi; 6. A. Ad fontis Aras; 7. A. Via Margutta; 8. A. Petronia Sallustiana; 9. A. S. Felice; 10. A. del Grillo; 11. A. Lantolae; 12. Tullianum; 13. Fons Juturnae; 14. Fons Lupercalis; 15. Piscina Pubblica; 16. Fons Mecurialis; 17. Fons Apollinis; 18. Fons Camoenarum; 19. Palude Caprea; 20. I due Velabri.

[2] The parish of S. Maria del Gonfalone lies between the Piazza degli SS. Apostoli and the Church of the Gesù.

ROME

Scale of Metres

0 100 200 300 400 500 600 700 800 900 1000

Subsoil water springs &c. and distribution of Malaria within the wall after Lanzi and Terrigi.

Springs	3	*Buona*	*Untouched*
Subsoil water		*Cattiva*	
District Boundaries		*Cattivissima*	

10,000 square metres; eleven of the most populous parishes average 188·97 for this area, fourteen others average 101·89 and the remaining twenty-one only 63·95. From these figures we may well suppose that though the Ghetto may be an admirable example of the value of density of population as a prophylactic against malaria, all the worst effects of overcrowding are manifest in a very marked degree in this favoured locality, and the evidence of two French writers on the subject is worth quoting, if only to dispel this illusion regarding the healthiness of the Ghetto, or to put it in its true light.

De Tournon (*Études Statistiques*, liv. i. cap. ix.) quoted by Colin says, "L'amoncellement des habitations, la saleté des rues, le défaut de circulation de l'air ne sont pas des causes morbides, et le quartier infect des Juifs est en plein sureté."

And Baron Michel (*Topographie Médicale de Rome et de l'Agro Romano*, 1833, p. 142), "Les habitants sont atteints de maladies des testicules, de hernies, de leucorrhées, de dartres de teignes, de scrofules, de rachitisme, de scorbut, d'ulcères aux jambes."

Whilst even Lancisi (*De Nativis*, &c., cap. xviii, 9) has, "Quid, quod in ipso Hebraeorum ergastulo, infelici alioquin prope Tiberim loco posito, miseros illos cernimus foedâ etiam vivacitate consenescere?"

In fact, though free from malaria, the Ghetto is the home of every other disease and a source of danger to the city, and the municipal authorities are to be congratulated upon the more or less complete removal of it now in progress. During the year 1691 malarial fevers were so rife in Bologna that Ramazzini says of the year, "nullus annus medicus quaestuosior, et gloriosior," and yet the Jews' quarter escaped the visitation.

That the gathering together of a large population in a city should diminish and even do away with malaria, and that parts of such cities, in which overcrowding exists to an extent sufficient to constitute a grave danger to the rest of the inhabitants, should be more free from the disease than those parts in which there is an abundance of light and air, is such

a direct contradiction of our knowledge and experience with regard to almost all other diseases that we must needs endeavour to find some explanation. We can only inquire in what respect the Ghetto is more favourably placed than other parts of Rome, but inasmuch as the Ghetto is after all only an exaggerated case of a town, and as all towns are less malarious than the open country, we have really to inquire in what respect the conditions prevailing in Rome differ from those in the Campagna.

The connection we have established between malaria and certain meteorological conditions naturally leads us to inquire whether a town differs in respect of these conditions from the open country. The question might at once be answered in the affirmative, and we might assert as an established fact that the mean temperature of a town is higher than that of the open country immediately surrounding it; that, by reason of the drainage and paving, the atmosphere is drier, and that in every way the climate is more equable; we might even go further and say that, in respect of each of these factors, the more densely populated parts of a town are more favourably situated than those in which the houses are more scattered. Nor is the reason far to seek, as Lancisi says the constant fires, the planting of trees as a protection against harmful winds, the construction of buildings, the paving of roads, &c. dry and purify the air and keep it in constant circulation.*

Lancisi regards this comparative immunity from malaria enjoyed by towns, as a proof of the soundness of his theory of the particulate origin of the disease; we have already seen how his objection to the cutting of the woods between Cisterna and the Pontine Marshes broke down when put to the test, and here again we find him arguing that the conditions prevailing in towns are such as to destroy this particulate poison. We cannot discuss this question here, but it

* Proculdubio ad tuendam ab arefacto solo salubritatem, valde conducit multitudo incolarum, qui accensis perpetuo ignibus, consitis adversus perniciales ventos arboribus, excitatis aedificiis, constratis viis, vociferatione, atque halitibus partim purum servant äerem, ne aliunde inquinetur, partim motu solvunt ac purgant, partim denique benigno sale volatili, implent ac vegetant (Lancisi, *De Adventitiis Romani Cœli Qualitatibus*, cap. v. § iii.).

may be remarked as somewhat strange that the very conditions, which as a rule favour the development of disease should in this case act as preventives.

The records of the observatory of the Capitol and the observations already detailed enable us to institute a comparison between town and country. In the following table the maximum, minimum, and mean, temperature and the excursion of the thermometer, together with the mean relative humidity recorded at the observatory of the Capitol, on the day on which each of the series of observations already recorded terminated, are placed side by side with the mean of all similar records obtained in each series of observations. The periods do not exactly coincide, but they are sufficiently near to one another for our purpose.

1885.	Mean. Temperature.	Maximum.	Minimum.	Excursion of Thermometer.	Mean Relative Humidity.
Capitol, July 22nd	27·0	32·3	19·1	13·2	55
San Paolo, July 21st & 22nd	26·3	35·9	17·3	18·6	74
Capitol, July 25th	26·9	30·8	19·6	11·2	60
San Paolo, July 24th & 25th	23·5	31·6	16·6	15·0	78
Capitol, July 29th	24·2	30·2	18·5	11·7	71
San Paolo, July 28th & 29th	23·9	31·1	14·7	14·4	79
Capitol, August 4th	27·7	32·9	22·9	10·0	67
San Paolo, August 3rd & 4th	27·3	36·7	22·9	13·8	81
Capitol, August 7th	31·1	36·5	21·6	14·9	45
San Paolo, August 6th & 7th	27·4	38·8	20·9	17·9	75
Capitol, August 15th	26·6	32·4	20·6	11·8	53
Tre Fontane, August 14th & 15th	24·8	34·5	18·4	16·0	73
Capitol, August 20th	24·5	28·5	17·9	10·6	67
Tre Fontane, August 19th & 20th	22·1	29·1	17·6	11·5	77
Capitol, September 12th	20·7	25·6	16·5	9·1	52
Vigna Deserti, September 11th & 12th	21·7	27·8	14·1	13·7	68
Capitol, September 19th	21·1	27·6	12·7	14·9	62
Isola Sacra, September 18th & 19th	18·4	26·0	12·9	13·0	85

The figures in the above table require little or no comment Up to August 20th, the mean temperature recorded at the Capitol was always higher than that of the Campagna; on

September 12th the temperature at the Vigna Deserti was one degree higher than at the Capitol, but, on the occasion of the next series of observations (September 19th) the temperature in the city was again higher than in the Campagna. In the same way up to August 19th the maximum was always lower and the minimum always higher in the city than in the country, and the excursion of the thermometer always less; in one case only was the maximum greater, the minimum lower, and the excursion greater at the Capitol than in the Campagna, namely on September 19th, and in every case the mean relative humidity recorded at the Capitol was not only less, but very considerably less than that recorded in the country, the means of the two places being in the ratio of 59 to 76, or an average difference of *seventeen per cent.* The mean excursion of the thermometer at the Capitol was 11·9 C. as against a mean of 14·8 C. in the Campagna, so that, considering only this small number of observations, we are able to assert, that the mean temperature of the city of Rome is higher, the excursion of the thermometer very much less than in the surrounding Campagna, and that the atmosphere does not contain anything like the same amount of aqueous vapour. There is but little doubt that if the necessary observations were made we should find that these differences diminished from the centre to the periphery of the city itself, that is to say, we have again a most striking relationship between meteorological conditions and the distribution and intensity of malaria.

Some account has already been given of the wretched state of the agricultural labourer in the Roman Campagna, and how by far the greater part of the cases of fever treated in the Roman hospitals are derived from this class; before we take leave of this portion of our subject it will be well to consider briefly the relation of the disease to the condition of the people and to their occupation. It is a matter of common observation that in all malarious countries it is the poor, the ill-fed and the ill-clothed who suffer most; and as in many countries in the tropics, the clothing of the natives is of the lightest, and that generally of cotton or linen, they are but ill

protected from the vicissitudes of the climate. The same may be said of their food; it is as a rule very deficient both in quantity and quality.

The evil effects of this deficiency of food and clothing are manifest when we compare the effects of the climate, say of India, upon natives and Europeans respectively; the comparison is most assuredly not in favour of the former as regards liability to malarial fevers; considering the army alone, the native troops suffer rather more than the Europeans, and yet during their period of service they are far better fed, better clothed and housed than in their native villages, in which, as has been mentioned, the disease not infrequently takes the form of a pestilence and decimates them. Europeans in the tropics suffer considerably from fever it is true, but the rate of mortality among them from this cause is low, and this can only be attributed to the fact that they are better fed, better clothed, and better housed than the natives, are not so much exposed to the violence of the climate, and when they are so exposed, understand better how to protect themselves against it. Travellers in unexplored tropical regions, though undoubtedly fever is one of the greatest dangers they have to dread, seem to be able to bear up against it, to recover, and continue their work so long as they are not overtaxed and have the means of living well; but many have fallen victims to the disease after the loss of stores and necessaries and the prolonged hardship and exposure entailed thereby.

The average health of Europeans resident in India has undoubtedly improved during the last thirty or forty years, and though the climate may perhaps in some degree have become less deleterious, the real explanation of the improvement lies in the fact that the experience which has been gained has begun to bear fruit, and it has been discovered that much of the supposed evil effect of the climate was in reality due to evil methods of living. It is now well recognized, that it is possible for a European to live in the tropics, and by discretion in habits, food and clothing, to retain his activity, and suffer comparatively little, either from the

excessive heat, or the malarial diseases which abound in these regions. Such being the case, it is not surprising to find that malarial fever is to a large extent a class disease, and that even in malarious countries, the well to do suffer but little from it. This is certainly the case in the Roman Campagna; we have seen that the greater number of cases is furnished by the lowest class of labourers, and of their condition we need say no more than that it could hardly be worse. True they are the most exposed to it, but an examination of the relation of the disease to occupation will show us that something more than mere exposure is required. Colin tells us more than once that the sentries at the gates, and in the outlying parts of Rome, suffered more from fever than those whose duties kept them within the city; similarly in the outbreak at the convict station near Tre Fontane, the prison guards were, as a rule, attacked more severely than the convicts. The reason for this is not far to seek; sentry duty, particularly if prolonged, as it often is from necessity, places a man in the worst possible condition for resisting heat by day, and cold and damp by night; he is condemned by the very nature of his work to inaction, and during the continuance of it, he must bear the heat and cold as best he may. The mounted herdsman of the Campagna, or "buttero" as he is called, though in reality much more exposed than the prison guard, does not suffer to anything like the same extent from intermittent fever. He may be in the saddle in the Pontine region for the greater part of the twenty-four hours, but his clothing and equipment are such as to enable him to defy the climate, and though the fatigue he may have to undergo is often very great, it is to a large extent of the nature of healthy exercise. The buttero has the means, and does not neglect to use them, of providing himself with a sufficiency of good food, and even in the heat of August, he carries at his saddle-bow a heavy woollen coat, which will cover him from head to foot, and which he always dons at sundown. The sportsmen who go down to the marshes of Ostia and Maccarese to shoot, endure an immense amount of fatigue and exposure; and though their occupation takes them to most unhealthy places

at the worst season of the year, they rarely suffer from fever, whereas the wretched agricultural labourer with barely sufficient food and clothing for the maintenance of life, falls a victim at almost the first opportunity.

It may be argued, and with truth, that the same is true of all diseases; those who are healthy and lead an active, vigorous life, and have the means of maintaining their bodies in a condition of vigour, by abundance of good food and proper clothing, resist all diseases better than those who are ill-fed, and ill-clothed, and whose organs are not maintained in a state of health and activity.

True though this may be in general, it is peculiarly so of malaria, and it may be laid down as a rule for the guidance of all persons exposed to a malarious climate that, the avoidance of excessive fatigue, the protection of the body against damp, and extremes of heat and cold, and the use of all such means as will tend to maintain or heighten the physiological tone of the system, will do much to protect the individual from malarial disease.

PART III.

CHAPTER XVI.

INTRODUCTION.

HAVING examined from all points of view, the conditions under which malarial fevers manifest themselves throughout the world, we must now connect these conditions with the phenomena of the disease itself, and determine, if possible, whether they be of themselves sufficient to account for the train of symptoms produced, or whether they play but an intermediate part by favouring the production of some poison, animate or inanimate, which is the real cause of the disease. Before we attempt to make this connection, it will be well to take a survey of our position, and formulate if possible something definite from the mass of facts which have been set out in the previous pages.

There are two factors which from first to last appear to be ever present, and we are fairly justified in considering them as constants in the problem, these are temperature and water. We began by showing that malaria decreased from the equator to the poles, and that all the world over it affected low damp land. We discovered that it disappeared at a sufficient altitude only to find that diminution of temperature largely controlled its limits in this direction, and that whenever in a malarious climate the disease was found at altitudes above that which appeared to mark the limit of its vertical distribution for a given latitude, local conditions were generally found to prevail which raised the temperature above the mean for this level.

The inquiry into the causes of the variations of local temperature led us to the conclusion that they were largely influenced by the local distribution of water, and more

especially of the subsoil water. Applying these general considerations to the investigation of particular localities, we found that what held good for differences of level represented almost by kilometres was equally true when the differences were reduced to metres. The investigation of the relation of cultivation to the disease only revealed the operation of the same constants, for we found that the true relation of cultivation, and especially of trees, to malaria, lies in the modifications of local climate which they produced, these modifications consisting in the equalization of temperature and the removal of excess of moisture from the soil. Our study of the effect of density of population upon malaria and the conclusive evidence adduced that the disease is incompatible with the conditions prevailing in large and populous towns, only resulted in the discovery that the aggregation of human habitations operates powerfully in equalizing local temperature, and that in all probability the covering of the soil with pavements and buildings largely contributes to this result by preventing free communication between the subsoil water and the atmosphere above it.

Finding that, from whatever point of view we regarded the conditions under which malarial fevers prevail, this question of temperature and moisture met us at every turn, we inquired minutely into the local meteorology of several exceedingly unhealthy sites, and obtained direct and positive evidence of a strict relationship between the disease and those conditions which tend to bring about great and violent variations of temperature, and as a practical confirmation of the correctness of our reasoning, we found conclusive evidence that in the province of Rome at least, the disease attacked those persons who either from insufficiency of food or clothing, or both, were least able to meet these violent climatic changes.

The issue before us therefore resolves itself into the following question:—Are these changes sufficient in themselves to account for the phenomena of the disease? Or, do they only favour the production of some specific poison or pathogenic organism which by its action upon the human body causes the well-known symptoms of intermittent fever?

We must review and balance carefully the evidence for and against either theory, and though of the two propositions only one can be true, we shall find that simple though the issue appears to be, the resolution of the problem is difficult and complicated in the extreme, and unfortunately, when all has been said that can be said on either side, it will be found that we have after all only arrived at an extreme probability, and that anything approaching positive proof of the truth or otherwise of either theory is still wanting.

Before we enter upon our task let us briefly consider the questions which will arise and the order in which they are to be discussed.

We shall have to consider, What is intermittent fever? What do we understand by intermission? Is the well-known intermittent temperature of ague only a symptom or does it in itself constitute the disease? The pathological changes which are admitted to take place in the tissues and organs of patients suffering from intermittent fever will next demand our attention, and any argument which may be based upon them as to the nature of the disturbance set up in the organism. Having in this way defined our position with regard to the disease itself, we will then consider in chronological order the various theories which have been advanced to account for the phenomena of the disease, and sum up the arguments for and against each in turn. There will then remain the arguments to be derived from the action of remedies, this will bring us to a restatement of the problem, and such a decision as to the nature and cause of the disease as the evidence will permit, reserving in conclusion perhaps the most important question of all—the prevention of the disease in the individual and the methods to be adopted for the cure of an infected country.

CHAPTER XVII.

THE PHENOMENA OF THE DISEASE.

THE general phenomena of acute malarial fever are very simple and easily described, a typical attack having the following characteristics: it begins with more or less prolonged malaise and lassitude, frequently accompanied by pains in the limbs, liable to be mistaken for rheumatism, but differing from rheumatic pains in being more deeply seated, and on this account commonly described by the patient as being in the bones. There is generally much headache and often nausea, with great disturbance of the digestive functions. If the attack be slight there may be nothing further to attract attention, and the whole of the phenomena may be, and often are, ascribed to an attack of indigestion, with which they are perfectly consistent. In most cases however, when these symptoms have lasted for a longer or shorter time, the patient begins to complain of feeling chilly; this sense of cold continues and increases without relation to the surrounding temperature, and no external heat, natural or artificial, is of the slightest avail to mitigate the sensation which increases and progresses until shivering and rigors are produced, sometimes so violent that the patient is compelled to lie down; the skin is cold and clammy to the touch and the discomfort is extreme. Presently these symptoms subside and are replaced by an equal sense of heat which gradually increases, the pulse quickens, the skin becomes hot and dry, and the temperature rises rapidly with all the external signs of fever. This state lasts for some time, and then the skin gradually begins to act

freely, drops of sweat form here and there, slowly at first, but soon so quickly that the patient's clothes or bedding may become soaked by it, and the sense of relief is intense; at the same time the temperature falls very rapidly to the normal, or even below the normal. As soon as the sweating stage is over, beyond the weakness and exhaustion produced, and a feeling of having been soundly cudgelled, the patient, if a strong man, and if this be the first attack, is generally not much the worse; indeed, as far as the author's experience goes, the effects produced on a previously healthy individual are by no means proportionate to the severity of the fever, and the rate of recovery is very rapid.

Such is an outline of a typical attack of ague. The great majority of cases, especially if they have been previously treated, or are of long standing, do not present such a regular course of phenomena; many are reduced to a prolonged malaise with heat and dryness of the skin, which slowly passes off, the patient being quite unable to state when the attack began or when it ended. The cold stage is very frequently absent and the sweating is often not well marked; these are however clinical variations which do not concern us at present. Attacks of this kind are well recognized as forming the prelude to other diseases, and the group of symptoms described are not in themselves necessarily malarial; it is their recurrence at regular intervals which constitutes true intermittent fever or ague.

The period of this recurrence varies in different persons and in the same person at different times, constituting quotidian, tertian, or quartan ague, according as the attacks are repeated daily, every alternate day or every fourth day. (The temperature curves of some very typical cases are given, Plate XXXII.)

In addition to these very simple forms there are many others which may be considered as the result of combinations or reduplications of these; for example, double tertian and double quotidian are very frequently met with, as are also combinations of quotidian with tertian and in some cases, by no means uncommon, these combinations are of such a nature

as to give the resulting fever a continued, or almost continued, character, so much so that if they occur in a non-malarious country and nothing is known of the antecedents of the patient the diagnosis of the disease may be somewhat difficult.

The regular periodic recurrence of the phenomena above described constitutes intermittent fever; if not interfered with the attacks generally tend to diminish in intensity, and the disease will as it were wear itself out and disappear; it may also be cut short by suitable remedies, or as is too often the case, especially among the inhabitants of malarious countries, the disease may continue in an irregular and ill-defined form, gradually wearing out the strength of the patient and rendering him a chronic invalid.

There is yet another peculiarity of the disease which will be found to have a very important bearing on its etiology, namely, that a person who has once suffered from intermittent fever is ever afterwards liable to a return of it, *without fresh exposure to a malarious climate*, and although the intervals may be long, extending even to years, the subject of them can never regard himself as absolutely safe; the body as it were acquires a habit which, though it may be rarely exercised, appears never to be forgotten. Lastly, and perhaps no less important than this continued liability is the change of type which takes place in successive attacks, and of this the author's own experience affords a very good example.

He was attacked on August 20th, 1885, at the close of the observations at Tre Fontane, by very grave double quotidian ague, which, after lasting some four days, yielded to treatment and disappeared leaving him weak but otherwise apparently well. Despite continual exposure in the interval, no further attacks developed themselves until June 1886, when the disease again appeared in the form of a well-marked tertian which lasted about ten days, again yielding to treatment.

About a week after this attack the author returned to England, and two days after his arrival was again the subject of tertian ague; the symptoms were very severe and necessitated change of air on recovery. Accordingly about a week after the

last attack the author left London for the north of England, and had hardly reached his destination when the disease reappeared in a very severe form, and continued as a tertian ague for more than a month. In the hope of ridding himself of the malady the place of residence was changed to a more bracing locality, and for a time the disease disappeared. After nearly a month of comparative immunity a slight cold brought about the return of all the symptoms with even greater severity than before, the duration of the attacks, still of the tertian type, being greatly increased, and the whole series of phenomena being perhaps better marked and more regular than in any previous attack, the temperature rising to 107°F. Despite the very high temperature and the longer duration of the symptoms, as on previous occasions, recovery was very rapid, and forty-eight hours after the last attack no ill effects were experienced.

All through the winter of 1886-87 slight attacks were experienced at intervals, each feebler and less characteristic than the preceding one, but still of the tertian type. These were followed by several months of freedom until in May 1888, it returned as a *quartan* ague; the stages were very badly marked, the rise of temperature often very slight, and in a few weeks the attacks degenerated into a perfectly periodic malaise and nothing more. In September, 1888, after a long interval of freedom, and coincidently with a marked fall in the atmospheric temperature, a fresh series of attacks began, generally slight, but with well-marked rigors and sweating; their period was very variable, beginning as quartan but afterwards becoming irregular and uncertain. The majority of them yielded to simple rest, and care as to food and clothing; very few required the administration of quinine or arsenic. Since this time there has been no well-marked return of the disease, though an occasional slight rise of temperature without obvious cause serves as a reminder that the habit is not yet lost.

Change of type is a common result of interference with the disease by the administration of quinine, arsenic, and other antiperiodic remedies, a double quotidian becoming simple,

and a simple quotidian, tertian; the general effect of these remedies being to lengthen the interval between successive attacks.

Intermittent fever may thus be said to have three important characteristics: periodicity, continued liability of the individual, and tendency to change of type.

We have thus far avoided all reference to the so-called remittent fevers, but the temperature curve will be readily understood if we conceive one access of fever beginning before the previous one has subsided, thus preventing the return of the temperature to the normal.

There are other types to which we shall have occasion to refer, especially those known as pernicious, a very large proportion of which are fatal. For our present purpose we must regard these malarial fevers as consisting of a simple fever which is repeated at regular intervals, and, that as the frequency of the attacks increases, the disease becomes quartan, tertian, quotidian, or by the combination or reduplication of these intervals, may assume all manner of types, passing through the remittent form in which the temperature, though it falls considerably, is not able to reach the normal before a fresh attack begins, to what is practically a continued fever, the intervals between the accesses being so short that the temperature scarcely varies from the higher limit, and the remissions so slight as to be of no importance to the patient.

How far this assumption that these fevers are all one and the same disease, only differing from one another in the frequency with which the individual attacks follow on one another, is a question which need not concern us at present, although all our experience tends to justify this view. The fundamental fact in all is the intermission; and we shall clearly not advance far in our attempts to explain the ætiology of these fevers until we arrive at some conclusion as to the nature and causes of this intermission.

CHAPTER XVIII.

PERIODICITY.

On the hypothesis that true intermittent, remittent and continued malarial fevers are all essentially one and the same disease only differing from one another in the length of the interval between the accesses of fever, we may make a comparison between the temperature curves of typical cases of each variety, and those obtained from a muscle by the use of a spring interruptor in the primary circuit. If the spring be long and its rate of vibration slow, each curve of contraction is perfect, and separate from the next, and if the speed of the recording surface and the length of the spring remain constant the interval between any two curves will, theoretically, be the same. If we shorten the spring to a certain extent we may so alter the rate of vibration, that there shall be no space between the curves, but that the instant one contraction is over a fresh one shall commence; if we shorten the spring still further the second contraction will begin *before* the first is over, and if we continue this process the contractions can be made to succeed one another with such rapidity that the muscle cannot relax, and the well-known curve of tetanus is obtained. If instead of one primary current, we were to use two, it would be possible so to arrange the interruptors that the muscle should be stimulated alternately by them at equal intervals of time; supposing the apparatus to be so arranged that the period of rest shall be exactly equal to the period of contraction, we should then obtain a curve which would

resemble that of tertian ague. If now the other interruptor be brought into action in such a way as to stimulate the muscle in the periods of rest, we shall obtain a curve which will resemble that of a quotidian ague though, from the manner in which it has been obtained, it would be more correctly described as a double tertian. Without entering into any further detail, it will be obvious that by means of an apparatus of this kind we could imitate the temperature curves of almost any type of malarial fever; the curve of tetanus would represent the continued form, and that showing the genesis of tetanus the remittent type, so that if we were to imagine the existence in the organism of a centre which when stimulated produced fever, in the same way that the stimulation of the muscle results in contraction, we could conceive the mode of origin of almost any type of true malarial fever on the hypothesis of rhythmic stimuli whose periods were in the ratio of 1, 2, 3, &c. We have as yet no ground for supposing that such is the case, but the hypothesis is convenient and will be of use later. The first question which naturally suggests itself is, does this rhythm show itself in the temperature curve in health or in that of any other febrile disorder, not malarial? The temperature of the human body in health exhibits a well marked periodic variation, rising during the day and falling during the night, and though the curve shows variations which are undoubtedly connected to some extent with the taking of food they are not abolished during starvation; that is to say, the temperature of the body is the result of a process or processes the activity of which is marked by a distinct periodicity. The exaggeration of this daily periodicity in the temperature in almost any febrile disorder is well recognized, and it is

[1] The following hourly observations of the human temperature in health are given by Jürgensen (quoted by Rosenthal; Hermann, *Handbuch der Physiologie*, Bd. iv., pp. 323, 324):—

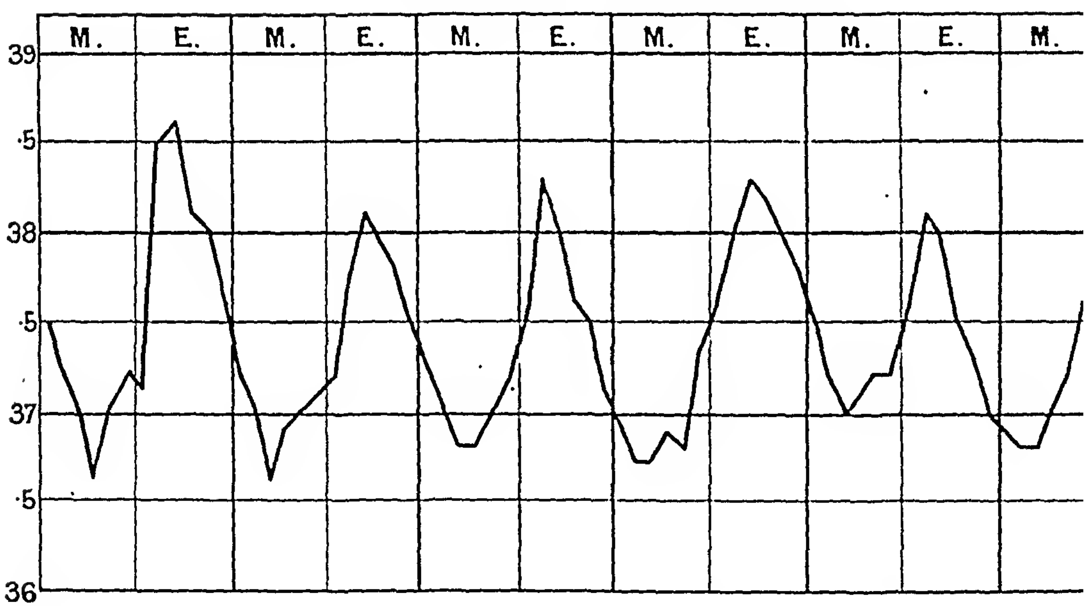
5 a.m.	6 a.m.	7 a.m.	8 a.m.	9 a.m.	10 a.m.	11 a.m.	12 noon	1 p.m.	2 p.m.	3 p.m.
36·6	36·4	36·5*	36·7	36·8	37·0	37·2	37·3*	37·3	37·4	37·3*
4 p.m.	5 p.m.	6 p.m.	7 p.m.	8 p.m.	9 p.m.	10 p.m.	11 p.m.	12 p.m.	1 a.m.	2 a.m.
37·5	37·5	37·6	37·6	37·7	37·5	37·4	37·4	37·4	36·9	36·7
3 a.m.	4 a.m.									
36·7	36·7									

The asterisks indicate times at which food was taken.

TEMPERATURE CURVES OF CERTA

To face p. 261.

PULMONARY TUBERCULOSIS.



sometimes very marked in chronic tubercular disease of the lungs (see Fig. I., plate XXXIII.)

We have spoken of the intermittence characteristic of malarial fevers as a "habit" which is not easily shaken off, and which only requires to be provoked in the proper manner, in order to manifest itself. It is a matter of common experience amongst those who have to treat disease in malarious climates, that in almost any disorder which has fever for one of its symptoms, this fever has a tendency to take on a markedly intermittent character, not observed in the same disease when occurring in a non-malarious country. A simple catarrh may, under these circumstances, become distinctly periodic; a surgical operation may be followed by a fever of well-marked periodicity, and even a true continued fever, such as typhoid, will often take on the malarious type; and not only will the temperature curve show this superadded peculiarity, but the periodicity itself will vary in different cases in much the same way as in cases of simple intermittent fever.

Thus judged by the temperature curve, any febrile disorder in a malarious climate may, and often does, resemble the disease in its ordinary form, *plus* intermittent fever; nor is this only a resemblance, for, if the proper treatment for intermittent fever be joined to that adopted for the special case in which it has made its appearance, the superadded periodicity will vanish, and the temperature curve will acquire the characteristics proper to the disease as studied in non-malarious climates.

It may be argued, and with some justice in these cases, that the individual has been infected by malaria previously, and that the diseases are simply coincident, but it is difficult to reconcile this explanation with the fact that the intermittence will not manifest itself until the other disease has begun, and if no special treatment be adopted will disappear with the recovery of the patient from the graver disorder; in fact, is a something added to it and not a separate but accidentally coincident disease.

This periodicity is always more or less to be expected in patients who have suffered from intermittent fever, but it is

of common occurrence in persons who, as far as their own personal knowledge and observation goes, have never suffered from ague, though habitually resident in a malarious climate.

Thus far we have spoken of periodicity as affecting febrile disorders; but those who have acquired intermittent fever at any time in their lives are often made aware that the phenomena have a wider range, and know what it is to suffer from headache or local neuralgia, having the most perfect periodicity, and which will only yield to those remedies which are equally useful in dealing with attacks of true intermittent fever; the neuralgia may arise from disordered digestion, defective teeth, or local injury, or from any other sufficient cause; but in a person who has suffered from intermittent fever, its manifestation will tend to exhibit a regular periodicity.

Consideration of cases of this kind serves to remind us that even in those who have never lived in malarious climates and certainly never have suffered from intermittent fever, these symptoms often exhibit a great tendency to periodicity, and that in such cases the so-called anti-periodic remedies, cinchona alkaloids, and the like, are generally useful.

Lastly, a person who has suffered from malarial fevers and subsequently resides in a non-malarious climate may, by falling ill of some other disorder, provoke a return of the ague; that is to say, he may be seized with typhoid fever and his temperature curve may exhibit a periodicity not usual in typhoid fever, and after recovering from the disease he may find that he is more liable than before to the return of his old malady, from which it would appear that the, as it were, almost forgotten habit was aroused by the more serious disease, and once aroused it is very easily provoked to manifest itself. In persons not long returned from malarious countries, and perhaps congratulating themselves on having got rid of their ague, an attack of indigestion or some other trifling disorder may bring back the disease and increase their liability to it for a long time afterwards. In some individuals the tendency of the disease to return is very small, and it seems as it were to wear itself out quickly, never to return,

at least it never does return. Such cases are not common, and as a rule they are cases in which the original attack was insignificant, and the residence in a malarious climate short.

Regarding malarial disease in the light of these peculiar characteristics, we begin to be aware that so far from being simple the phenomena are very complicated, and that it will be by no means an easy task to discover an explanation of them which shall satisfy all the conditions required. The question begins to suggest itself, Is it not the periodicity which requires an explanation rather than the fever? and ought we not to regard the other phenomena as subordinate, and define the disease as the acquirement by the organism from some unknown cause of a periodicity of function which it did not before possess, or at least did not manifest?

CHAPTER XIX.

PATHOLOGICAL ANATOMY.

In considering the pathological anatomy of malarial fevers we must distinguish somewhat carefully between the chronic and the acute forms. In chronic cases the enlargement of the spleen, or "ague cake," as it is popularly called, is often evident enough during life, and could not fail to be recognised post-mortem. In the acute forms of the disease the post-mortem appearances are such that a large number of very competent observers have declared that in the bodies of persons dead from recently acquired acute malarial fever there are no lesions appreciable to the naked eye. This is undoubtedly true in the sense that such differences as exist between the post-mortem appearances of health and acute malarial disease are so slight as to be easily overlooked even by skilled observers. Slight though these differences may be, they are none the less evident and characteristic when once recognised, though it must be admitted that there *are* cases in which, from the post-mortem appearances alone, it would be difficult to pronounce a positive opinion as to the cause of death. As a rule, all that the most careful examination will reveal is a slight enlargement and softening of the spleen, no more than is often met with in cases of typhoid fever; and in the bodies of those who have died from those forms of the disease in which coma and delirium are characteristic symptoms there is often a well marked injection of the meninges of the brain. With these exceptions the whole of the organs of the body appear to the naked eye to be perfectly normal.

Further experience of the post-mortem appearances of acute malarial fevers and a careful comparison of them with those of health lead us to recognise a certain peculiar brown tint of the liver and spleen as characteristic, and that the cortical substance of the brain is of a slate-gray colour, more pronounced than normal. These changes in colour of the spleen, liver, and brain, with slight softening of the first named, with or without enlargement, constitute all the abnormal naked-eye appearances presented post-mortem by a case of acute malarial fever, and it will be readily understood how many competent authorities have been led to state that acute malarial fever was characterized by no special anatomical lesions.

It is to Dr. Laveran that we owe the best and most detailed description of the pathological changes which take place in malarial fevers, and no apology is necessary for the reproduction of the main points of the account given by him in his work, *Traité des Fièvres Palustres.*

ACUTE MALARIAL FEVER.

The Blood.—To the naked eye the blood presents no appreciable difference from the normal. A cursory examination with the microscope reveals however the presence of a number of pigmented elements of two kinds: leucocytes with granules of pigment imbedded in their protoplasm, and certain hyaline masses containing pigment; these are met with in the greatest number in the blood of the vena portæ and in the vessels of the liver and spleen. We shall return to a minute consideration of the changes in the blood in the chapter on ætiology, when it will be necessary to discuss in detail the nature of these pigmented bodies; a simple statement of the fact of their existence will suffice here.

The Spleen.—Increase of weight and volume is, as a rule, the most apparent lesion of the spleen, and in some cases this may amount to three or four times the normal. The form of the organ is usually but little affected; being distended, it is more globular and rounded than the normal.

The capsule is thin, tense, and very friable. The abnormal state of the whole organ reveals itself when an attempt is made to remove it in the usual manner; it ruptures under the hand, and comes away in fragments. Spontaneous rupture of the spleen has been observed occasionally in the so-called pernicious forms of the disease, and, considering the general condition of the organ, it is somewhat remarkable that this accident is not of more frequent occurrence; it is said to be not uncommon in cases of long standing in which the spleen is greatly enlarged and adherent to the surrounding parts.

The colour of the organ on section, instead of the usual deep red, is a more or less pronounced brown, compared by Maillot to the colour of chocolate mixed with water. This brown coloration is due very largely to the pigment in the spleen-pulp, and is regarded by Laveran as characteristic. The preparation of sections of the spleen for the microscope in these cases is very difficult, the material breaking up with great ease; such sections show that the pigment is distributed in the spleen-pulp and is absent in the Malpighian corpuscles (see Figs. A and B).

The capsule of the spleen is normal or is only slightly thickened. Laveran states that in sections of the spleen from cases of typhoid fever he has never found any pigmented bodies, and that the only alteration produced was that resulting from great congestion of the organ.

The Liver.—In general the liver is slightly augmented in volume and in weight, but the variations from the normal may be insignificant. The one constant change is in the colour of the organ, which is *uniformly* brown in section; the colour is not unlike that which is found post-mortem in those parts of the liver which have been in contact with the intestine, but which may be readily shown to be merely local stains, whereas in the malarious liver the characteristic brown colour pervades the whole organ. Histological preparations afford evidence of congestion, and the blood vessels are more or less filled with the pigmented elements before mentioned (see Fig. C.)

The Kidneys generally present a perfectly normal appearance, and it is only in microscopic sections that the pigment granules in the blood vessels become apparent. The number of these is generally much less than in the liver and spleen, and they are usually found in the glomeruli (see Fig. D.)

The Alimentary Tract is usually normal, as is also the peritoneum; the blood vessels contain more or less pigment,

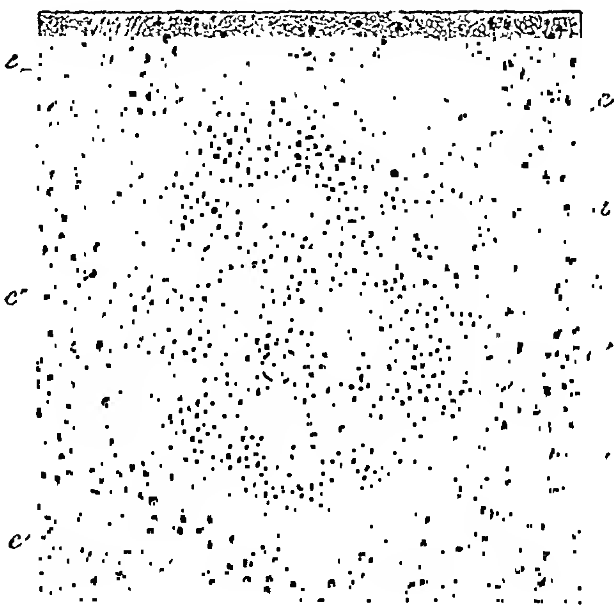


FIG. A.

SECTION OF SPLEEN FROM A CASE OF PERNICIOUS MALARIAL FEVER.

The central portion of the figure is occupied by a Malpighian corpuscle, *b*; *a*, *a'*, central arterioles; *c*, *c'*, *c''*, hyperæmic zone around the corpuscle; *e*, *e'*, bundles of connective tissue—the vessels are dilated and filled with blood and pigmented elements. Mag. 150 diam. From Laveran.

and Laveran states that in one case which came under his observation, the peritoneum showed numerous minute patches of hæmorrhage. The mesenteric glands are not hypertrophied.

The Lungs and Pleuræ are generally healthy; occasionally there is evidence of congestion; the blood-vessels contain pigment granules.

The Muscles present no special characteristics, the capillaries contain variable quantities of pigment.

The Central Nervous System as a rule appears healthy, except in those cases in which delirium or coma were prominent symptoms, in which the meninges are very frequently inflamed. As before said, the cerebral convolutions are of a dark, slate grey colour which appears to be partly due to hyperæmia,

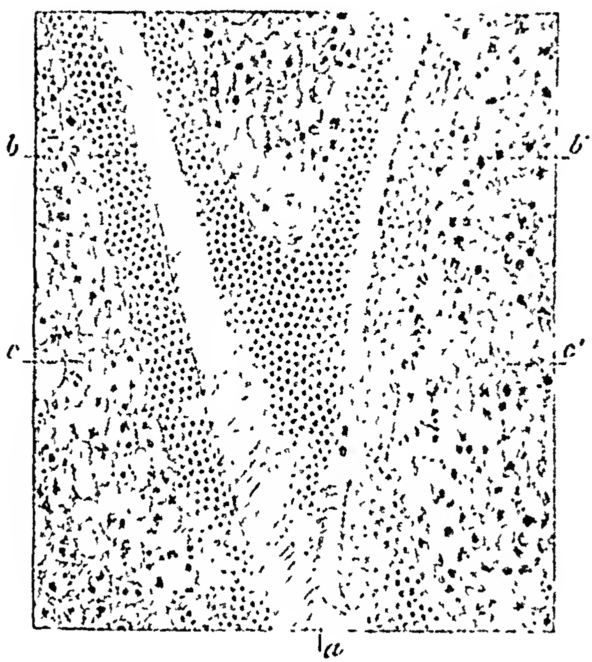


FIG. B.

SECTION OF SPLEEN FROM A CASE OF PERNICIOUS MALARIAL FEVER.

a, An arteriole dividing into two branches; *b*, *b'*, sheaths of lymphoid tissue accompanying the arterioles, and which when seen in transverse section give rise to the appearance indicated in Fig. A; *c*, *c'*, splenic parenchyma—the vessels are dilated, filled with blood, and contain numbers of pigmented bodies. Mag 150 diam. From Laveran.

but chiefly to the presence of pigment in the capillaries. (see Fig. E.)

Occasionally both these appearances are wanting, but so far as is at present known no other variations from the normal occur.

The pigment is entirely confined to the blood vessels, and the coloration produced is therefore proportional to their

number. The pigment granules are often so numerous that, as Laveran describes it, the vessels appear to have been injected with some hyaline substance holding a black,

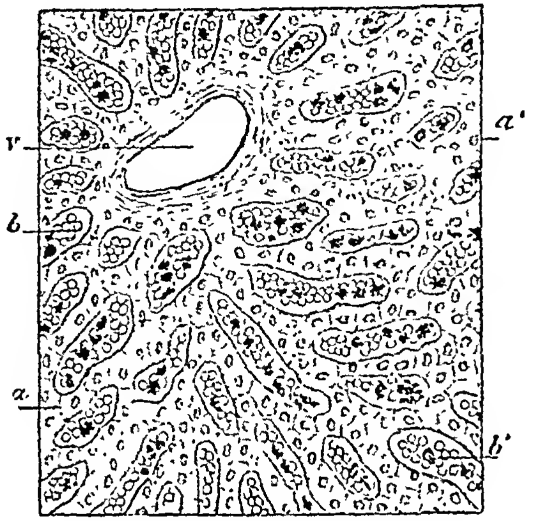


FIG. C.

SECTION OF LIVER FROM A CASE OF PERNICIOUS MALARIAL FEVER.

Hepatic cells; *b*, *b'*, capillaries filled with corpuscles and pigmented elements; *v*, intra-lobular vein. Mag. 170 diam. From Laveran.

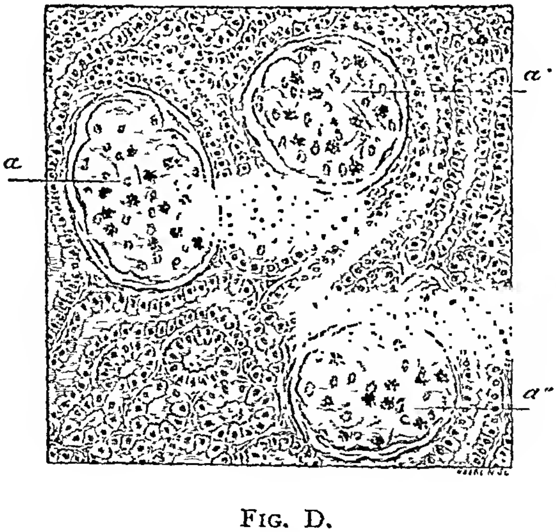


FIG. D.

SECTION OF KIDNEY FROM A CASE OF PERNICIOUS MALARIAL FEVER.

a, *a'*, *a''*, Three glomeruli containing pigmented elements. Mag. 170 diam. From Laveran.

pulverulent matter in suspension; the hyaline substance is indistinguishable in sections mounted in Canada balsam, and nothing is then visible but the pigment granules. These granules of pigment are invariably *within* the vessels, *never* in the brain substance outside them; the small vessels of the cord present the same features as those of the brain, and, with the

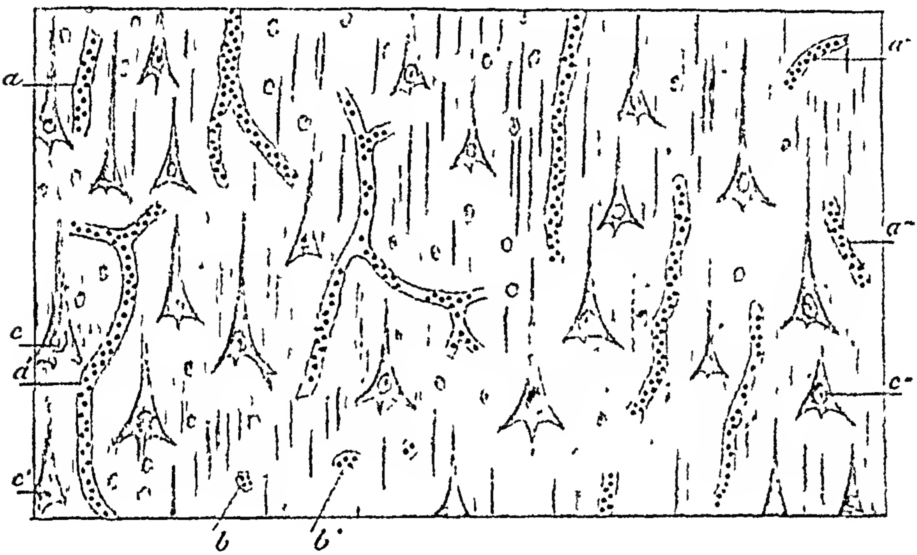


FIG. F.

SECTION OF THE GRAY MATTER OF THE CONVOLUTIONS OF THE BRAIN, FROM A CASE OF PERNICIOUS MALARIAL FEVER, COMATOSE TYPE.

a, *a'*, *a''*, *a'''*, Capi llaries containing a great number of pigmented elements; *b*, *b'*, capillaries in transverse section, also with pigment granules; *c*, *c'*, *c''*, cells with pericellular spaces exceedingly well marked. Mag. 300 diam. From Laveran.

exception of the presence of this pigment, the whole of the central nervous system is otherwise perfectly normal.

The Marrow of the vertebræ, ribs, sternum, and long bones, has a characteristic brown tinge, due to the presence of pigment precisely similar to that which is found in the capillaries of the brain and other organs.

CHRONIC MALARIAL FEVER.

The bodies of those who have died from chronic malarial disease present lesions which may be said to be gross in comparison with those resulting from the acute form of the malady: they are moreover very frequently complicated by secondary lesions, or by those of other disorders from which the patient has suffered.

The pathological anatomy of chronic cases as far as naked eye appearances are concerned, resolves itself into enlargement of the spleen and liver, the former being often enormously increased in size, and much indurated, with no characteristic colour; the liver shows signs of congestion, and often of cirrhosis: not infrequently there is evidence of chronic nephritis and pneumonia.

The disease in many chronic cases, sets up a condition of the organs which, as Laveran points out, is often very misleading, post-mortem examination reveals the existence of very extensive cirrhosis of the liver for example, and the question arises, Is this the result of malaria or no? "It often happens," says Laveran, "that malaria after having given birth to a disease of the liver, kidneys, or lungs, disappears, either spontaneously, or under the influence of specific treatment, the patient has no more fever, he is cured of the malaria, the pigmented elements disappear from the blood, but the organic lesions of the spleen, liver, and kidneys, persist and become accentuated, often to such an extent as to cause death," that is to say, a patient may die of a disease which though originating in malaria, is in no sense specially characteristic of malaria, and unless something be known of his antecedents, the real cause of the disease may never be suspected.

Considering the tissues and organs in the same order as before, we find the following to be the most important points in the pathological anatomy of chronic malarial fevers.

The Blood.—Laveran states that the total mass of the blood is materially diminished, and that there is general anæmia of all the tissues and organs. The pigment granules are most

usually found in the spleen, but may be altogether wanting, and the diagnosis will then altogether depend upon the general condition of the spleen and the antecedents of the patient.

The Spleen is always increased in size and weight, and is sometimes of enormous bulk, filling one half the abdominal cavity, the lower border reaching into the left iliac fossa, whilst the upper border forces up the diaphragm, to which it is very frequently adherent. The general form of the organ is retained, and its consistence is such that "placed upon the lecture table it does not collapse but retains its form" (Laveran). The capsule is irregularly inflamed and thickened, of the normal thickness in some parts, and several times the normal in others. The inflammatory attachment to the diaphragm is a common seat of rupture of the spleen, in consequence of the strain on the capsule caused by the movements of respiration. According to Laveran, the peritoneal covering is more thickened than the proper capsule of the organ. The splenic veins are dilated and gorged with blood, in which pigment granules are present in greater or less number. The splenic pulp is compressed between the thickened parenchymatous structures, and, relatively to the enormous size of the organ, occupies but a small space. The Malpighian bodies are but little altered. The lesions of the spleen in chronic malaria may be summed up as consisting in inflammatory congestion and hypertrophic cirrhosis.

The Liver in malarial cachexia is almost always diseased, often to such an extent as to be the direct cause of death. As in the spleen, there is a considerable increase in the bulk and weight of the organ, it is of somewhat harder consistence than in health, and its colour rather darker; the capsule is generally thickened, and the capillaries gorged with blood, and the hepatic cells being compressed, tend to diminish in size and number. In the blood vessels are found the same pigmented elements which were described as occurring in acute malaria, but in smaller number. Malarial cirrhosis of the liver is said by Laveran to be only distinguishable from that arising from other causes by the presence of this pigment matter, and he is also of opinion that it may be started by the

malaria, and continue after this has been cured, so that in some cases the pigment may disappear, and the antecedents of the patient will be the only guide to the origin of the lesions.

Kidneys.—Next to the liver the kidneys are perhaps the most affected. According to Kiéner (*Tribune Médicale*, 26 August, and 2 September, 1877) the lesions of the kidneys are of two types, engorgement and atrophy.

In the first case they are enlarged and increased in weight, the surface is smooth, the colour dark red, and the congestion is especially marked in the pyramids. Sometimes the vessels are distended to such a degree as to produce interstitial hæmorrhages, hyaline casts are also often found in the urine. In the atrophied kidney, the organs are small and lumpy, the capsule adherent, and the colour resembles mahogany; under the microscope alterations in the connective tissue and in the epithelium may be recognized. Whether malarial nephritis tends more to the interstitial or to the parenchymatous type, is apparently still a matter of some doubt.

Alimentary Canal.—Inasmuch as dysentery is a common disease in almost all malarious countries, it is not unusual to find post-mortem evidence of it in cases of chronic malaria, but how far it has any direct connection with the disease is uncertain.

Lungs.—Chronic malaria is not unfrequently associated with a species of chronic pneumonia, which, in the experience of the Roman physicians, is often accompanied by the development of tubercle.

From this brief statement of the anatomical lesions occurring in acute and chronic malaria respectively, we may say that the acute form is chiefly characterised by the existence of pigmented elements in the blood, especially in the capillaries of the spleen and liver; whilst in chronic malaria, there are profound lesions of the spleen, liver, kidneys, and other organs, so closely resembling those produced by other diseases, as only to be distinguished from them by the presence of the pigmented bodies, especially in the capillaries of the spleen, and that in cases of long standing even these may be wanting

The one distinguishing feature of malaria is therefore the presence of this pigment, and apparently in no other disease has any similar pigmentation of the organs been observed. So constant is the presence of melanæmia in malarial disease that we are justified in saying that if the cause and nature of melanæmia could be discovered, we should have advanced far towards a settlement of the question, What is *malaria?* The facts bearing upon the production of pigment in the blood, are so closely connected with the researches which have been made with a view to the discovery of some pathogenic organism as the prime cause of the disease, that it will be well to defer all consideration of them until we come to deal with these researches.

CHAPTER XX.

THE PERIOD OF INCUBATION.

In most acute infectious disorders there is an interval varying in different diseases, but more or less well defined for each, between the exposure of the individual to the infection and the manifestation in his body of the characteristic symptoms. This period is called the period of incubation; does such a period exist for malarial fevers?

If by period of incubation we mean, an interval of time constant, or practically constant for any given disease, we may at once answer the question as regards malaria in the negative, for if we were to expose a number of individuals, in the same malarious locality, at the same time, for the same period, and as nearly as possible under the same personal conditions, we should find:—

1. That not all would be attacked.

2. That there would be the greatest possible variety in the gravity of the cases of those who did acquire the disease; some might die, whilst others would be so slightly affected as hardly to attract attention.

3. Those who were attacked would not all exhibit the same type of the disease.

4. They would not all manifest the symptoms at, or about the same time, but at most diverse periods after exposure.

5. Some of those exposed, and assumed after more or less prolonged observation to have escaped infection might (*A*) develop the symptoms, months or even years afterwards, in a non-malarious climate; (*B*) suffer from some other disorder

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in a non-malarious climate the temperature curve of which, in their cases, would exhibit intermissions or remissions not proper to the disease from which they were suffering, and which would require the exhibition of the so-called antiperiodic remedies for their removal.

We have therefore clearly no right to speak of a definite period of incubation in malarial fevers, inasmuch as this period if it can be said to exist at all, may vary almost from hours to years. There is probably no disease in which individual idiosyncrasy has so palpable and profound an influence, nor is there any disease in which it is so difficult to define what constitutes exposure to infection, or to determine the time and duration of such exposure in any individual case.

If we could conceive a person suddenly transferred from a place where malaria was unknown, to another in which it prevailed in a serious form, it would undoubtedly be possible to determine approximately the date at which the disease manifested itself, and further, if the attack were well defined, the time of its onset could be stated with great accuracy. Interesting though such an observation would be, from what has just been stated, it is clear that no argument drawn from such a case would be of the slightest value. Nor is this all, it is a very open question whether the first well defined attack of ague is to be taken as indicating the commencement of the disease, on the contrary all the evidence is against such a supposition. The author's own case affords an example of the uncertainty of the period which may elapse between exposure to the infection, and the first definite manifestation of the symptoms of the disease.

He was more or less constantly exposed during nine weeks in exceedingly malarious localities before he was attacked; others in the same localities, perhaps more constantly resident than the author, though certainly by no means so much exposed, fell ill of fever two or three weeks before, whilst a friend of the author's passed several days and nights in the Pontine region in July 1885, and escaped entirely. Other cases might be cited, in which the exposure in a known malarious locality was exceedingly short, and the onset of the

disease almost immediate, but in all malarious countries the argument *post hoc, ergo propter hoc,* would almost invariably lead to a wrong conclusion, for it is difficult if not absolutely impossible, to affirm that any given individual has never been exposed to infection, previous to the particular occasion after which the disease developed itself.

It has been observed in Algeria, that troops just arrived from France and marching from Bona to Constantine, a distance of about one hundred miles, through a country highly malarious, are never attacked *en route*, and that it is only some days after arrival at Constantine, that the disease manifests itself, and this interval may extend to a month or more. Laveran * says, "I for my own part have never observed a case of sudden invasion of fever in those who, up to that time being free from all malarial disease, traverse for the first time a malarious district," and he quotes Maillot to the effect that it is very common to meet persons who have never had fever in Algeria, but who some time after their return to France, have exhibited all the characteristic symptoms of the disease.

This tendency of the symptoms to show themselves for the first time, not during actual residence in the country in which it was acquired, but at variable, and sometimes very long intervals after return to a perfectly healthy climate, is one of the most curious and important facts connected with the disease, and if we are to regard the first well defined attack of ague as the first manifestation of malarial disease, we must in the face of the evidence which has been adduced, abandon all idea of the existence of a definite period of incubation. Examples of this appearance of the disease in an apparently healthy individual on change of place of residence, are very common in all malarious countries; a case which came under the author's personal observation is perhaps worth recording. An individual, aged about thirty years, and who was employed in one of the government offices in Rome, obtained a somewhat lengthy furlough, in order to visit friends who resided in the province of Aquila, he, according to his own statement not having been more than twenty miles away from Rome for

* Laveran, *Traité des Fièvres Palustres*, pp. 27, 28. Paris, 1884.

more than ten years, and never, so far as he was aware, had he suffered from fever in any form. Within less than forty-eight hours after his arrival at his destination, he was attacked by intermittent fever of a very grave type, for which he was treated, and as soon as he was sufficiently recovered, he returned to Rome, where the disease clung to him for some weeks and then disappeared, nor did it return during the remainder of the author's stay in the city (nearly two years).

The same appears to be the case with individuals who have had ague, and have been apparently cured in the country in which it was acquired, they are exceedingly liable to relapse on change of climate.

This apparent non-existence of a definite period of incubation and the great length of time which may elapse between exposure to the necessary conditions and the development of the phenomena of the disease as generally recognised, should in the author's opinion lead us to suspect that the first definite attack of ague, instead of being the first manifestation of the disease, is rather the culmination of certain processes set up in the body, and which in themselves do not interfere with the patient's health or comfort sufficiently to attract attention, and that it is possible that these preliminary stages of the malady, may be of such a nature as to require special circumstances for their development into ordinary intermittent fever, that is to say the train may be laid, but it requires to be fired before its effect becomes manifest.

The existence of premonitory symptoms in ague, excepting those which are the immediate precursors of an attack, appears to have escaped the attention of most observers, but that they exist, and that their treatment is of great consequence to the sufferer, is in the opinion of the author beyond question. Prof. Silvestrini * has drawn attention to them, and as he enjoyed exceptional opportunities for the study of the effects of a malarious climate, on individuals recently arrived in Sardinia, from parts of the mainland where malaria is unknown, they are of great interest in relation to this part of our subject.

* *La Malaria. Lezioni di Giuseppe Silvestrini.* Parma, Luigi Battel, 1885.

He says, "In those recently arrived in malarious climates, especially if they be of robust constitution, and have come from localities in which malaria is unknown, the clinical observations acquire a more than ordinary importance.

"When such an individual coming from a district entirely free from malaria, especially if he be a mountaineer from the Alps or the Appennines, takes up his residence in Sardinia, he at first experiences a grateful sense of comfort, a tranquillity of mind and a degree of energy, which causes him to smile incredulously when he is warned of the necessity of living with regularity and avoiding as much as possible the cold air of evening, and the dews at night. After a short time, which varies with the season and the habits of the individual, this optimism begins to be shaken, the appetite diminishes, there is a sense of oppression in the epigastrium, an almost unconquerable sleepiness, not infrequently accompanied by eructations, a sense of heat in the stomach, flatulence, and constipation, alternating with slight diarrhœa, weariness, and mental and physical apathy, and disinclination for work. The mental condition is also somewhat modified, the temper becomes uncertain, and though in some cases the gradually increasing melancholia may perhaps be set down to a constant desire for return to their native land, in others, who have always been wanderers, and in whom nostalgia is unknown, there is a strong desire to quit the climate which was at first apparently so agreeable, and to remove as far as possible from it. To these phenomena, which have not the slightest tendency to disappear, after some days, even if the subject of them change his mode of life, there is added an unusual scantiness of the urine; the urine passed is dense, highly coloured, and always deposits a large amount of sediment; the mouth is foul and bitter, there is aversion to food, especially animal food, and a more or less strong desire for stimulating drinks. All these symptoms come on by degrees, and continue for a considerable time with alternations of improvement and aggravation, until at last the patient after some fatigue greater than usual, or some indiscretion in food, or after having exposed his body when greatly heated to some sudden

chill, is stricken with an acute sense of malaise, headahce, rigors and sweating, frequently giddiness, vomiting, insomnia and some delirium. That is to say he has an attack of fever, not violent perhaps, and his temperature may not rise to more than 39° C. or at the most 40° C. When this attack is over the patient becomes aware that he has ague; he is treated, or acting on the advice of some friend, takes a dose of quinine; the attack is not repeated and the symptoms which preceded it slowly disappear, especially if before the quinine or even after it, a purgative have been administered. Clearly the patient will say, it was the quinine which cured the disease, but," as Prof. Silvestrini goes on to say, "how is it that if one deceives the patient, as I have often done, and limits the treatment to the administration of some mild purgative, an alkaline powder or some innocent drink, given solely to satisfy the demands of the patient (at the most lemonade with some magnesia and syrup of raspberries) the method is equally attended with the most brilliant results? And how is it that if the patient be an intelligent person and willing to submit to the disease for a day or two without treatment, that it disappears in much the same way as if he had taken a gramme or more of quinine?" Prof. Silvestrini then proceeds to lay special stress on the existence in all malarious countries of these solitary attacks of fever, preceded by gastro-intestinal catarrh and the other disturbances of health which have been described. If they are not treated, or if the treatment is confined to the simple administration of quinine and the subject of them returns to his usual habits, after a variable interval the attack returns, and by degrees the interval between the fits is shortened until a well developed case of ague of definite type is the result. Prof. Silvestrini attaches great importance to the characters of the urine, which he says indicate great hepatic disturbance; and he asserts that a large number of persons, though living in districts where malarial fevers of grave type prevail, seem never to get beyond this stage, and though continually far from well, never develop a true attack of ague.

It would be very easy to accumulate a great mass of

evidence of this kind, and those who have lived in malarious countries and observed the state of health of the people, will hardly require to be reminded of it, and it would appear to be at least probable that, the first definite attack of fever exhibited by a patient is only an explosion resulting from causes which have been operating in his body for a long time. Unfortunately these premonitory symptoms are as a rule of so trifling a character, and cause the subject of them so little annoyance, that no attention is called to them and in the few cases in which complaint is made and medical advice sought, the patient will be told, and with reason, that there is little or nothing to treat and that regular habits, simple food with a little rest and change of air, will soon remove the symptoms such as they are. If any medicine be given it will invariably take the form of quinine or arsenic, the malaise and lassitude disappear and no more is heard of the patient. Cases of this kind are exceedingly common in Rome and the Campagna; very few appear to require special treatment and a still smaller number receive any.

Strangers seem to be more liable to these symptoms than the natives, or what is perhaps more true, notice them more; this is specially the case with persons coming from the hills into the Campagna; not infrequently they are regarded as malingerers. Whether these symptoms are to be considered as the forerunners of intermittent fever is a matter on which it is somewhat difficult to form an opinion, all we can say is that in many cases, if neglected, true intermittent fever supervenes and that on this ground it is at least highly desirable that they should be treated and their return if possible prevented.

These considerations lead us to the conclusion that the onset of malarial disease is rarely if ever sudden, that the period of incubation if such can be said to exist at all, is exceedingly variable, and that in all probability whatever be its cause, we should rather regard the disease as a habit, which may be acquired and possessed for a very considerable time, without the individual being aware of it, until such circumstances arise as will cause it to manifest itself.

CHAPTER XXI.

THE CIRCUMSTANCES UNDER WHICH MALARIAL FEVERS MAY BE ACQUIRED, AND THEIR POSSIBLE INFLUENCE ON THE TYPE ASSUMED BY THE DISEASE.

THE various conditions prevailing in, and peculiar to, malarious climates have been described at some length, and we might define the circumstances under which the disease may be acquired as, exposure to these conditions. This, though it may be true, helps us but little to understand how they are to be applied in order to bring about an attack of ague in a particular case.

It has already been shown that the disease is intimately related to class and occupation, that hardship and privation increase the liability of the individual, whilst good food, and proper clothing and housing, tend to diminish it; in other words, there are means which may be adopted by which the risk is reduced to a minimum, and the extent to which an individual is in a position to avail himself of these means largely determines his liability. Bearing this in mind, the importance of an examination of individual cases becomes obvious; for in almost all civilized countries the conditions of individuals are so various that we can form little or no opinion from general statements. In the case of a city like Rome it is fair to assume that those who can afford it will live in those parts which are known to be healthy, and that in this way a division of the city into a rich and poor quarter will inevitably result, and as a consequence the true significance of statistics as to the relative healthiness of its various parts is somewhat obscured.

Those who from choice or necessity inhabit the unhealthy parts of the city suffer a two-fold liability to the disease, for not only may they acquire it in the locality in which they habitually reside, but their employment is such as to expose them to additional risks; further, their position is such that they cannot avail themselves of those means of avoiding the disease which are known to be more or less efficacious. In this way the relative unhealthiness of certain quarters is to a very large extent exaggerated. The case of the inhabitants of the villages on the line of the Jumna Canal is somewhat different. These people probably present a far greater similarity of condition than the inhabitants of a European city, and we can more confidently affirm that the new conditions affect all alike, or practically so. We will examine the condition and liability to the disease, of certain classes of Campagna labourers, and, by a process of elimination, endeavour to reduce the problem to its simplest terms.

The ordinary day-labourer of the Campagna has furnished us with the bulk of our statistics, and something has already been said as to the state of misery and poverty in which he lives. The evidence given before the many Commissions on the state of the Agro Romano throws further light upon it which will help us to understand how he acquires the disease. One witness says, "A state of life almost savage, produced by isolation and abandonment, slender pay, bad and scanty food, render the condition of the few *contadini* scattered over the Roman Campagna, from every point of view miserable in the extreme. Housed for the most part in straw huts, or in wet caves; after the long fatigues of the day they have no other food than a little maize flour mixed with water, and no other drink than water, often drawn from stinking pools." *

And again, "It does not require any words to explain under what horrible conditions these unfortunates exist; but things are far worse when one knows that hardly has the harvest begun to show signs of maturity than, in order to protect themselves from theft, frequent in a country so deserted (as the Pontine region), they are driven to take up their abode

* Pinto, *L'Agro Romano*, p. 137.

day and night in the fields without even a hut which might protect them from the cold morning mists, which are never wanting in a district so rich in water. The most lucky are those who can set up four stakes in the ground and build a platform two or three metres above the soil, on which they may stretch themselves at night."[1]

The clothing of these poor folks is in harmony with their miserable conditions of life; a cotton shirt, a ragged coat, and a still more ragged pair of trousers, or sometimes, particularly towards the Neapolitan frontier, knee-breeches, and in place of boots, *ciocie*, or sandals made of leather with a piece of linen wrapped round the leg for stockings. "The first luxury with which a Campagna labourer will provide himself, especially in the unhealthy districts, if he be not absolutely destitute, is a great-coat of peculiar and characteristic cut, to protect him from the rain and the rigours of the climate."[2]

Thus badly fed, clothed, and housed, the Campagna labourer has to meet the enormous range of temperature which has been shown to prevail, and when we consider that his clothing is insufficient to protect him from the heat of the sun by day, we may imagine the effect produced by the relatively intense cold and drenching dews at night. This is the class which furnishes the largest number of grave cases of fever.

It has been already stated that the "*buttero*," or mounted herdsman, occupies a very superior position to that of the agricultural labourer; his food and clothing are, if rough, good and sufficient, and the fatigue he has to endure is perhaps not excessive. His duties, though they do not involve his exposure to the conditions described at the worst season of the year, nevertheless take him to exceedingly unhealthy places, and may frequently necessitate his being out all night at times, and in places where others, not so well provided, may be, and are, attacked by fever. His horse saves him much fatigue; he is well shod and is hardly ever seen without a heavy great-coat to protect him alike from the sun by day and the damp and cold by night.

[1] *Annali di Agricoltura*, No. 77, 1884, p. 53.
[2] *Inchiesta Agraria*, p. 812.

The Campagna carters often lead very hard lives; such rest as they can get for many days, sometimes even weeks together, being obtained by sleeping on their vehicles as they travel from place to place. Their condition is still infinitely superior to that of the agricultural labourer; they do not sleep on the ground, their carts are provided with movable screens to protect them from the wind and sun; they are fairly well clad, many wear woollen shirts, and all carry some extra covering which can be used in case of need; many of them do undoubtedly fall ill of fever, but as a class, as far as the author's experience goes, they are not especially liable to it. Their business takes them from town to town, and their home is usually at one or other end of their journey; and hard though their life may be, they do not sleep on the ground, or in caves and straw huts, and they have some intervals of repose which are denied to the agricultural labourer.

The *Carabinieri*, whose duty it is to patrol the roads night and day, are undoubtedly greatly exposed, and many of them are attacked by the disease, though serious cases are not common among them, unless they are quartered in exceptionally unhealthy places. There is a large amount of evidence to show that the fever is acquired in their place of residence, more frequently than in the execution of their duty; indeed, it is from examples of this kind that one is led to the conclusion that malarial disease is not so quickly acquired as is generally supposed, but that a more or less lengthy exposure to the necessary conditions is requisite. We have seen that the prison guards at Tre Fontane suffered more than the convicts; and taking all these examples into consideration, we are driven to the conclusion that the risk run is to a very large extent directly proportional to the ability of the individual to provide himself with the means of resisting the violent climatic changes by an active life, and a proper supply of good food and clothing.*

There is one feature of malarial fevers which has not yet

* "They should wear warm clothing, and should indulge in a plentiful diet of flesh, with wine and spices." Lind, *Diseases Incidental to Europeans in Hot Climates*. 4th Edition, p. 285, 1788.

been referred to, and which requires some notice, and that is the precision with which, in many cases, the patient will name the place and the hour at which he acquired the disease.

The attack is generally attributed to a violent chill or similar shock to the system received at a certain time and place, such as by entering caves, cellars, pozzolana pits, churches, and other cold places, whilst heated, or sometimes by emerging suddenly from such places into the full heat of the sun. An analysis of a number of examples which came under the author's notice showed that in every instance the individuals had been long resident in a malarious district and that, with very few exceptions, the resulting ague was by no means the first attack. Be this as it may, those whose employment leads them to run the risk of exposure to these sudden changes, thoroughly realise the danger incurred, and provide against it; but from carelessness or other causes, the precautions are sometimes neglected, and in these cases an attack of fever is a common consequence.

The Romans as a people are particularly careful to avoid chill in any form, and the persistency with which they will carry overcoats and extra wraps, at times when an inexperienced person would regard them as a useless encumbrance, cannot fail to strike the observer. A very short residence will, however, suffice to convince the most sceptical of the wisdom of the practice.

Carters and others who are compelled at times to halt with their charges on the road for several hours at night invariably light fires in such a position that the heat and smoke will keep them dry and warm, the smoke possibly serving to diminish radiation. The author has on many occasions questioned these men as to why they lighted these fires, and more especially why they fed them with wet branches; the invariable answer was "*per cacciar via la febbre*," *i.e.*, to drive away the fever.

Our evidence then, from an examination of the condition of the classes most affected by the disease, shows that exposure to extreme variations of temperature is certainly one of the factors, or at least includes one of the factors, which

produce intermittent fever in the individual. All who can, endeavour to avoid exposure of this kind, if possible, and those who cannot avoid it, attempt to mitigate it in some way or another, those who succeed best suffering least.

It has been shown that there is no definite period of incubation in malarial fever, and the amount of exposure necessary for the acquirement of the disease is, and must remain, undetermined, for the simple reason that it is more than probable that no two individuals are susceptible in the same degree. Malarial fevers present a variety of types, and the relation of the type assumed by the disease to the nature and circumstances of the infection, using the word in its broadest sense, require investigation. We are seeking a basis on which to found an explanation of the nature and mode of origin of the disease in the human organism, and the causes of the well-known variations of type presented by the disease will help us materially in arriving at a conclusion.

VARIATIONS OF TYPE.

In the chapter of periodicity, it was pointed out, that an intermittent fever might become remittent and a remittent continued, on the hypothesis that the accesses of fever succeeded one another with such rapidity that the intermission or remission had not time to show itself, so that without taking into consideration the reduplicated and compound forms of the disease, we have at least five well-marked types, quartan, tertian, quotidian, remittent, and continued, which, in the order in which, they have been named, may in some degree be regarded as representing an increasing intensity of infection. The distribution of these types throughout the world is exceedingly instructive, for if we inquire into their relative frequency in different countries, we find the quartan type to be characteristic of high latitudes, and the continued of the tropics, whilst the tertian, quotidian and remittent mark the stages between the two extremes. We have already found that malarial fevers increase in intensity as we

approach the tropics, and we now understand what this increase of intensity means, namely, a progressive diminution of the period of rest between the individual accesses of fever.

This change of type with latitude is well shown even in Europe, and we might almost divide the continent into zones according to the type of malarial fever most common in each. In North Germany, quartan ague is the rule; in Hungary the tertian type begins to predominate; in Italy, quartans are rare, and quotidian frequent, and many of the graver forms are not unknown, whilst if we cross the Mediterranean to Algeria we find quotidian ague the common type and remittents very frequent. In India and in tropical Africa the remittent and continued forms become still more common and the quartan and tertian correspondingly scarce.

The following table from Dr. Léon Colin's book[1] will make this variation of type with the latitude more clear.

RELATIVE FREQUENCE OF THE DIFFERENT TYPES OF FEVER IN THREE DIFFERENT LATITUDES.

	Cases.	Remittent.	Quotidian.	Tertian.	Quartan.	Irregular.
Vienna[2] . .	3,125	—	1,293 36 %	1,495 42 %	243 7·6 %	95 3 %
Algeria[3] . .	4,849	614 12 %	2,984 62 %	1,206 24 %	21 0·5 %	
India[4] . .	5,617	5,116 91 %	439 7 %	62 1 %		

That is to say, as the mean temperature increases the interval between the accesses of fever tends to become shorter.

[1] *Traité des Fièvres Intermittentes*, p. 138.

[2] *Vienna Hospital Reports* for the years 1855–62.

[3] Finot, *Compte Rendu du Service Médical de l'Hôpital Militaire de Blidah pendant l'Année*, 1842.

[4] James Raynald Martin, *Twelve Years Statistics of the General Hospital of the Presidency of Bengal.* See also Morehead, *Clinical Researches on Diseases in India*, p. 17, 1860.

This being true of variations of latitude we ought to find some change of type in any given locality corresponding with the season of the year, and such is in fact the case. In high latitudes malarial fevers only make their appearance during the heats of summer, and as we approach the equator we find that the beginning of the fever season is marked by the types of lower periodicity, and that the more intense forms, such as quotidian and remittent, are characteristic of the period of most intense heat.[1]

Lastly, although malaria is to be regarded as a strictly endemic disease, it now and again assumes the form of an epidemic, increasing in intensity in those districts where it already exists, and showing itself in others which as a rule are entirely free from the disease. These epidemic outbreaks invariably occur in years of exceptional heat; this was the case in the epidemics in North Germany in the years 1826 and 1868.[2]

It has also been observed in the Roman Campagna, that in years in which the fever reaches an exceptional degree of intensity, it appears to enlarge its sphere of action and to affect places not generally regarded as in any sense malarious; such irregular manifestations of the disease in these places are generally of a very mild type.

Whatever therefore may be the cause of malarial fevers, the universal influence of temperature upon their distribution and upon the type assumed by them admits of no doubt soever; the relation is apparently absolute, and there is no escape from the inference that temperature is the most constant and important factor in their ætiology. Mere heat however is not the cause, for malarial fevers are not common, nor very intense in some sub-equatorial climates in which though the average temperature is high, it is extraordinarily constant; and again the hot season in tropical countries is not the fever season, but the beginning of the rains, when the temperature instead of being almost constant night and

[1] Colin, *loc. cit.* p. 159.

[2] Haeser, *Lehrbuch der Geschichte, &c.* Von Ritter in Oberndorf, "Studien über Malariainfection" (*Virchow's Archiv*, April, 1869.)

day, is subject to enormous variations. Even in the Roman Campagna it is a matter of common experience that, so long as the heat is intense and not broken by occasional heavy rains, the fever diminishes considerably, to break out again with increased violence at the beginning of the autumn rains, and it is at this period of the year that the daily excursion of the thermometer is the greatest, so that the part played by the water appears to be the bringing about of the conditions under which these violent changes are possible.

Water is however not necessary in all cases in order to render a district malarious, and India furnishes numerous examples of this. The sandy deserts of western Rajpootana are terribly malarious, and yet water is some two-hundred feet below the surface and no floods or heavy rains occur to deposit any organic matter on the surface. Jacobabad in Scinde is 220 feet above sea-level, the surrounding country is flat, sandy and dry, water is twenty-seven feet from the surface and is brackish, that used for drinking purposes being brought from the Indus, fifty-two miles distant, by small canals and stored in tanks. The highest rainfall from 1851 to 1870 was *eight inches* the lowest *two and a half inches,* and one might imagine such a place incapable of producing fever, yet the number of cases among the native troops quartered there between the years 1852 and 1860 varied annually from 688 to 2,136 per 1000 men; the heat is excessive and the variations of temperature very great.*

Aden is a sun-baked rock where vegetation does not exist and where water is a luxury, and yet fevers of the remittent and continued type are common. In the year 1859, 356 white troops quartered there yielded 242 cases of continued fever and 82 of intermittent and remittent.

Hongkong is built upon a bare granite rock with little or no vegetation, and yet fevers of a grave type are very common there.

These are cases in which water can have little or nothing

* *Report of the Royal Commission on the Sanitary State of the Army in India,* ii. pp. 860, 861. Quoted by Oldham, *loc. cit.* p. 45.

to do with the production of the disease, but the temperature of these places is notoriously subject to violent changes, the result of the rapid and unchecked radiation which begins the moment the sun goes down. By day, these dry rocks and hard sandy deserts are heated to an intolerable temperature under a fierce sun, and the heat accumulated is radiated by night with such rapidity that advantage is taken of the natural process for the production of ice.

Thus far we have been led to regard temperature and water as constant factors in the production of the disease, the latter is clearly no longer so to be considered, but only as a very frequent auxiliary. Temperature still is left, and even this we must qualify to sudden and violent changes of temperature. The evidence adduced thus far is sufficient to fully justify us in assuming, that, whatever else we may subsequently discover, these great variations of temperature are a necessary quality of a malarious climate, and that exposure to them without adequate means of resistance is likely to be followed by an attack of intermittent fever.

It will perhaps not be out of place here to consider the question of racial immunity and acclimatization. In the ordinary sense in which these phrases are usually understood neither can be strictly applied to malarial disease, for no race appears to enjoy immunity, nor does acclimatization appear to be possible except in a very limited sense. There are however certain facts bearing on these questions which are exceedingly interesting, though they add somewhat to the difficulty of understanding and explaining the phenomena of the disease.

It has been observed ever since the disease began to be studied statistically, that whenever English troops have been moved into malarious countries they suffered from fevers of a somewhat different type from those prevalent among the natives. During the Walcheren expedition, the English soldiers were attacked by remittent fevers whilst the natives suffered from the intermittent type exclusively. In India though the percentage of cases in the native army is somewhat greater than among the European troops, the latter yield

more cases of remittent fever than the former, as the following table from Hirsch will show:[1]

	Intermittent.	Remittent.
Europeans	12·8%	4·2%
Natives	16·8%	1·4%

The same authority quotes figures as to the relative mortality in Ceylon from malarial fevers, which leave little room for doubt that though the natives by no means escape, the Europeans suffer more from the graver forms of the disease and have therefore a somewhat higher rate of mortality. The same fact has been observed among the French troops in Algeria, and all writers on malaria have described this peculiarity of the disease, which may be taken to indicate some approach to acclimatization.[2]

But in addition to these differences between natives and Europeans, which seem to indicate a certain limited acclimatization, similar differences exist between Europeans newly arrived in the tropics and others who have been resident for some time; the new comers are more liable to the remittent forms of the disease than the residents, though the percentage of cases of fever of *all* types is much the same for both.

The following statistics given by Colin[3] show this difference between the resident and newly-arrived troops in Algeria and in Rome.

ARMY IN ALGERIA. 1865.

Remittents 3,199, of which 359 were relapses, or one-ninth.

Intermittents 15,080, of which 4,296 were relapses, or one-fourth.

ARMY IN ROME. 1865.

Remittents 449, of which 18 were relapses, or one twenty-fifth.

Intermittents 1,682, of which 322 were relapses, or one-fifth.

[1] *Loc. cit.* p. 172.

[2] Colin, *loc. cit.* pp. 147–49, quotes a large number of authorities on this point.

[3] *Loc. cit.* p. 146.

So that whilst no race enjoys complete immunity from the disease, some suffer more than others, and acclimatization appears to be possible to a limited extent in that Europeans who have resided for some time in a malarious country suffer less from the graver forms of the disease than new comers.

CHAPTER XXII.

ÆTIOLOGY OF MALARIAL FEVERS.

THE theories which have been advanced to account for the origin of malarial fevers may be very conveniently divided into two groups; those which attribute the disease to the operation of some pathogenic organism, and those which seek to explain the phenomena as the result of physical or other causes.

We will here confine ourselves to a simple statement of these various theories, reserving the discussion of their relative merits to a succeeding chapter.

The earliest theory as to the origin of malarial fevers attributed the disease to emanations or exhalations from marshes or marshy soils; these emanations, as we have already seen, were generally supposed to be of the nature of minute organisms, which entering the human body, set up changes in it which resulted in the production of the well-known phenomena of the disease. The *prejudizio palustre* has endured from the time of Hippocrates to the present day, and though its authors had no means of proving the existence of these supposed organisms, still less of demonstrating their mode of action upon the human body, it was regarded as a good working hypothesis, and was acted upon as such, though, as has already been shown, much of the evidence adduced in support of it, has an entirely different bearing. It will be convenient to consider the second group of theories first, namely, those which do not require the interference of a pathogenic organism.

These theories may be subdivided into two groups; those which account for malaria as the result of the absorption by

the body of certain emanations from the soil, and those which regard the disease as an effect produced by what may be called physical causes, such as violent changes of temperature, or by some peculiar physical property of the soil.

Boudin [1] was of opinion, that malaria was due to certain chemical products given off by various species of plants, such as *Anthoxantum odoratum*, *Chara vulgaris* and others.

Bouchardat,[2] on the other hand attributed the disease to a poison which he supposed generated by certain infusoria, and explained the absence of malaria in localities apparently well suited to its development, by the absence of these infusoria, or by the presence of certain plants which destroyed the poison as fast as it was produced. None of these theories have stood the test of investigation, nor do they satisfy the apparently very various conditions under which the disease manifests itself. The same may be said of those theories, which sought to account for the disease as dependent upon the chemical constitution of certain soils, or as the result of gaseous emanations from them. We have seen that no soil is of necessity free from malaria, and the action of the gases which have been accused of producing the disease is well known, and affords no explanation whatever of the phenomena of malaria, nor of its occurrence in many localities in which these gases are certainly not developed The unsatisfactory character of all these emanation theories. if we may so call them, has led some investigators to look to purely physical causes for an explanation of the facts ; of these only two need claim our attention.

Dr. Leon Colin says, "I think even, that far from having to seek the cause of the fever in marsh vegetation, it is on the contrary rather in the absence of this vegetation that one may find it. For my own part, in a word, the fever is caused by the vegetative power of the soil, when this power is not in action, or when it is not exhausted by a quantity of plants sufficient to absorb it. This is so far the case that in the marshes themselves, vegetation appears to be the most necessary

[1] *Traité des Fièvres Intermittentes*, Paris, 1841.
[2] *Annuaire de Thérapeutique*, 1866.

condition for the diminution of their pestilent character; stagnant waters also, which are surrounded by a belt of spontaneous vegetation, or whose surface is covered by water-plants, are infinitely less dangerous than swampy areas which present no active vegetation, but only detritus as do salt marshes."[1]

He does not however explain what is to be understood by this *puissance végétative du sol*, or vegetative power of the soil, still less does he account for its mode of operation upon the human body.

Dr. Oldham[2] is of opinion that the disease is due to the action of the violent climatic changes, which he endeavours to show prevail in all malarious countries, upon the human organism, in fact "that malaria is chill" (p. 185), and though he does not explain the *modus operandi* of these climatic vicissitudes, he adduces a large amount of evidence to show that those who are able to avoid them, suffer least from the disease. This theory has found favour with a large number of observers.[3] We may say of the whole of these theories, as to the origin of malarial fevers, that they are rather of the nature of suggestions, than of theories supported by evidence.

The greater part of them may be summarily rejected as affording no explanation of the phenomena of the disease, whilst the so-called "Chill Theory," or rather the evidence used to support it, will require careful consideration, as the connection of this evidence with the disease is too close to be disregarded.

We have now to review that group of theories in which a pathogenic organism plays an essential part.

The first definite attempt to connect malarial disease with microscopic organisms was made by Dr. J. H. Salisbury in the United States in the years 1862–66. He found in the sputa and mucous expectorations of persons suffering from ague, "a great variety of zoösporoid cells, animalcular bodies, diatoms, dismidiæ, algoid cells and filaments, and fungoid

[1] *Traités des Fièvres Intermittentes*, p. 14.

[2] *What is Malaria?* London: Lewis, 1871.

[3] Maillot, Faure, Folchi, Espanet, Armand, Philippe, Burdel, Meyersohn, Köstler, Minzi, Black, Ridreau, Weir, Munro, Morrison, and others.

spores. The only constant bodies, however, uniformly found in all cases, and usually in great abundance, were minute oblong cells, either single or aggregated, consisting of a distinct nucleus surrounded by a smooth cell-wall, with a highly clear, apparently empty space between the outside cell-wall and the nucleus." He further found that the cells did not occur in the saliva of persons living above the ague line in the district in which the investigations were made, and by exposing glass plates in aguish localities, he satisfied himself that these spores were found only in those places in which malaria might be acquired, and failed to find them in others which were known to be free from the disease,* or in his own words, "so far as I have examined (and my observations have been widely extended), I have never found a case of ague, *in situ*, where I did not find these plants growing near; and *vice versâ*, I have never found these plants growing in any locality but that (if such localities were inhabited) intermittent or remittent fever or both, prevailed in proportion to their extent and profusion."

Not content with this, Dr. Salisbury placed boxes of earth containing an abundance of these spores in the sleeping apartments of several individuals, and in most cases after a variable period some of them were attacked by the disease. He describes five species of *Palmella*, to which he gives the name of *Gemiasma*, and of these he says, "The species are many, all of which have hitherto been regarded as innocuous. There is strong evidence for believing, however, that the minute species that are developed in such abundance in the above-named localities, and the spores of which become elevated and suspended in such multitudes, in the heavy humid night exhalations of ague districts, are decidedly poisonous to the epithelial surfaces of the body with which they come in contact, and are the true source of intermittent and remittent fevers."

In the year 1869 Dr. Pietro Balestra examined the low forms of life present in the air and water of the marshes of Ostia and Maccarese at the mouth of the Tiber, and was struck by the constant occurrence of a microphyte of

* *American Journal of the Medical Sciences*, January, 1866.

characteristic form which he cultivated and carefully studied (Plate XXXIV.).[1]

This alga, to which he gave the name of *Alga miasmatica*, was found to require an abundance of air for its growth and development, and if submerged in the water, it speedily ceased to grow, broke up and decomposed. It was killed by solutions of sulphate of quinine, and also by solutions of arsenious acid. Examination of the air of the marshes by means of aspirators and apparatus for collecting dew, showed that the spores of this alga were very widely distributed, and according to Dr. Balestra, in direct proportion to the intensity of the malaria prevailing in the district in which they were collected. Further, after inhaling the air of a large vessel in which this alga was growing, on two or three occasions, Dr. Balestra was attacked by fever.

The *Alga miasmatica* was studied by Lanzi and Terrigi,[2] and pronounced by them to be *Cladophora* or *Oedogonium*, both species having a very wide distribution.

Safford and Bartlett considered that in *Hydrogastrum granulatum* they had discovered the cause of malarial fever; Archer in *Chthonoblastus aeruginosus;* Bargellini in *Palmoglea micrococca;* and Selmi in an organism very similar to that described by Dr. Balestra, apparently for the sole reason that these organisms were found in abundance in the marsh water investigated by the respective authors.

Lanzi and Terrigi, however, showed that the diameter of the spores of the organisms described by Safford and Bartlett and by Archer was greater than that of the capillaries; it was therefore impossible that they could enter into the circulation.

In 1873 Griffini made a number of experiments upon dogs and rabbits by the intravenous injection of dew collected over marshes and rice-fields. This dew contained a large number

[1] This Plate is a reproduction made by Dr. Balestra's permission from the original figure in his work, *Ricerche ed Esperimenti sulla Natura e Genesi del Miasma Palustre Rome*, 1877.

[2] Lanzi e Terrigi, *Il Miasma Vegetale o Malaria ed il Clima di Roma. Memoria letta all' Accademia Medica di Roma*, il 28 Maggio, 1876, p. 15.

1

2.

Alga Miasmatica (Balestra)

1 Young, with spores
2 Old, disintegration commencing

of organisms of various species, and the operation was followed in many cases by a rise of temperature amounting to from one half to one and a half degrees centigrade, but the spleen was in no case affected, nor was there any change produced in the microscopic characters of the tissues.[1]

In the year 1870 Lanzi and Terrigi studied the organisms found in the mud of numerous malarious localities in the neighbourhood of Rome, and in the marshes of Ostia and Maccarese, and finding that an alga, *Monilia penicillata*, was almost invariably present, they were inclined to regard it as the cause of the disease; but further investigation showed that many other species had the same claims, and the authors abandoned the theory that malaria had its origin in an organism in favour of that of a poison resulting from the decomposition of vegetable matter (*prodotto cadaverico vegetale*). They, however, continued their researches in the following year, inoculating animals with mud from various localities, and causing others to respire air which had been made to pass over large quantities of the same mud. Some of the animals had fever, others developed abscesses, and in some there was slight evidence of splenic and hepatic disturbance with traces of pigment in the organs, but the results were very far from conclusive.

In 1879 Professors Klebs and Tommasi-Crudeli published the results of their researches into the origin of malarial fevers.[2]

These investigations were conducted with very great care and ingenuity, and comprised an examination of the air, water, earth, and mud of various localities in the Roman Campagna. Great pains were taken in order to reproduce artificially all the conditions prevailing in marshes, and the organisms of the soil were thus cultivated and examined. These researches resulted in the isolation of an organism which is thus described in the original memoir (p. 30):

"Rods of the length of five to ten micromillimetres, which

[1] Griffini, *Relazione intorno alle Esperienze ed Osservazioni sulla Rugiada dei Luoghi miasmatici*. *Bullettino crittogamico*, Anno I. Milano, 1874.

[2] *Studi sulla Natura della Malaria memoria dei Professori Edwin Klebs e Corrado Tommasi-Crudeli.* Reale Accademia dei Lincei Seduta del I giugno, 1879.

as development proceeds are converted into tortuous filaments, which divide into segments by the formation of clear spaces in the protoplasm, or less frequently separating membranes. These filaments, on the surface exposed to the action of the air produce numbers of short segments, and in the interior of these, spores, which may make their appearance before or after division has taken place. The spores occupy the centre of the two extremities of the segments, or there may be a spore in the centre as well as at the two extremities. When the division into segments does not take place (the spores) multiply, becoming continually smaller and filling the interior of the filament with a granular mass."

Explanation of Plate (XXXV.).—This plate is an exact reproduction of that in the original memoir.

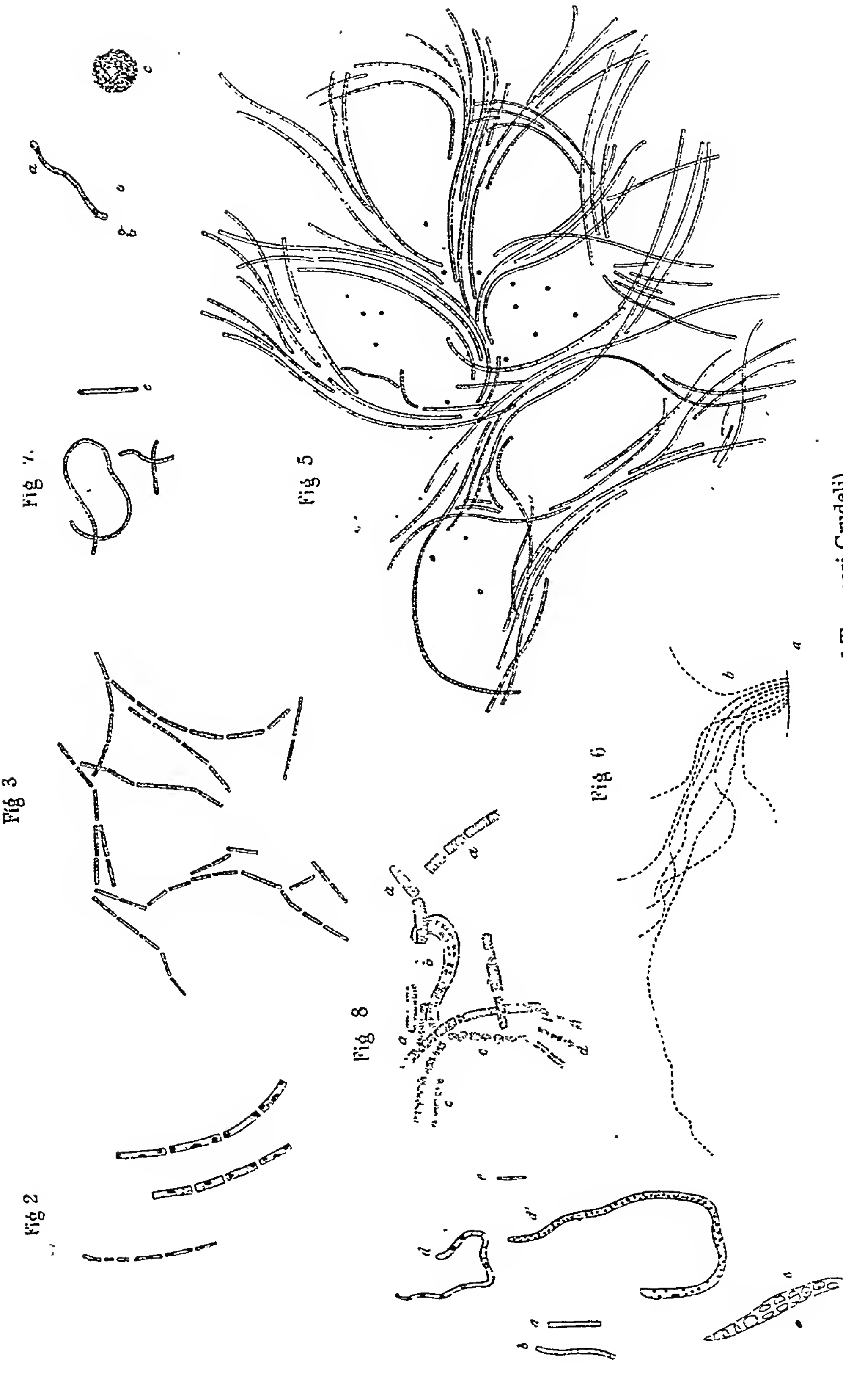
Fig. 7. Homogeneous filaments looped and tortuous, found on April 15th, in culture of mud from Caprolace. C, shows a rod containing at each extremity a bright granule.

Fig. 1. Other forms found on the same day in the same culture. (The numbering of the Figures 1 and 7 is due to an error of the lithographers.) A, rod showing no signs of division. B, homogeneous rod, with transverse division. D, filament containing many bright granules, observed at noon on April 15th. D′, the same as seen at two in the afternoon of the same day. E, fusiform cell not belonging to the series showing the development of the bacillus. F, small rod with two terminal granules and one central.

Fig. 2. Articulated filaments, some of which contain homogeneous protoplasm, others a median, parietal nucleus, others one central, and two terminal nuclei. From the same culture kept in an air-chamber (Zeiss 1—12th, oil immersion, Oc. No. O and No. IV.).

Fig. 3. Articulated filament, with homogeneous protoplasm from the same culture (Zeiss 1—12th, Oc. No. II.).

Fig. 6. The same filaments, disposed in groups, as seen in the same culture on April 26th (Zeiss E. Oc. No. II.). The portion marked B, stretched from the margin of the preparation to the centre.



Bacillus malariæ (Klebs and Tommasi Crudeli).

Fig. 4. A, bacillus, with two terminal spores. B, free oval spores contained in a coagulated lymph. C, lymphatic cell. Forms seen on April 22nd in the air chamber, No. 7, and in which lymph from rabbit, No. 1, had been under cultivation for twenty-four hours.

Fig. 5. Bundles of homogeneous and articulated filaments crossing one another in various directions, seen in the same culture on April 23rd.

Fig. 8. Forms observed in a culture of organisms derived from air taken at Ninfa and Fogliano, in urine, and in a cultivation of mud from Caprolace in isinglass. (Drawn as seen with Zeiss 1—12th, and Oc. No. IV.).

A, A, A, articulated filaments full of small brilliant granules. B, division of this granular mass. C, D, first signs of this division.

This organism was cultivated in various media, and a large number of experiments made upon rabbits by intravenous injection, and the authors claim to have induced in this way true intermittent fever, and to have produced the characteristic enlargement and pigmentation of the spleen.

The observations of Klebs and Tommasi-Crudeli excited general attention for a time, and may be considered as the starting point of all subsequent researches in this direction.

In 1881 and 1882 Dr. Laveran communicated to the Paris Academy of Medicine the results of his studies of malaria in Algiers, which marked a new phase in the inquiry, namely, the careful study of the blood of malarious patients and the changes produced in it by the disease.

The presence in the blood of patients suffering from the disease, of leucocytes charged with black pigment, had been recognized by several observers, and Dr. Laveran found in addition "certain spherical elements, others cylindrical or crescentic of very regular form, very distinct from the leucocytes charged with pigment. I had suspected," he says, "for a long time the parasitic nature of these bodies, when on November 6th, 1880, while examining one of the spherical pigmented elements in a preparation of fresh blood, I noticed with joy at the periphery motile filaments of the animated

nature of which there was no room for doubt." (Laveran, *loc. cit.*, pp. 154, 155.)

The relation of these bodies to the disease, and their identity with those described by other and independent observers requires that we should consider in detail the author's description of them.

Dr. Laveran describes four forms which he names No. 1, No. 2, motile filaments, and No. 3.

Form No. 1.—These bodies are cylindrical and tapered at their extremities, generally curved or crescentic, and pigmented at their centres.

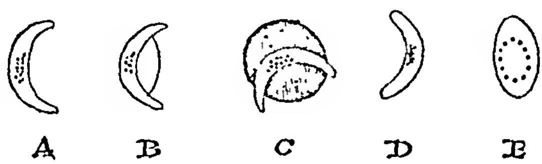


FIG. A.

A, B. Form No. 1, tapered at either extremity. C, Form No. 1, attached to a red corpuscle. D. Form No. 1, rounded at its extremities. E. Oval form intermediate between Nos. 1 and 2. (Mag. about 1000 diameters.)

They are 8–9·1000ths of a millimetre in length, and about 3–1000ths of a millimetre in diameter at their centres, the extremities are sometimes very pointed (A and B), sometimes they are more rounded as (C). They are transparent and colourless, except near the centre, where there is always an aggregation of granules of pigment. In rare cases the pigment is collected at the extremities. Frequently the horns of the crescent appear to be connected on the concave side by a fine line as in (B). When one of these bodies is attached to a red corpuscle, it presents the appearance shown in (C); the attachment is, however, slight and apparently quite accidental. Side by side with these, other forms are occasionally seen in which the curvature is very slight, and others more or less oval in shape (E), which appear to be intermediate stages between Nos. 1 and 2; in these the pigment is more regularly disposed.

The form No. 1, though not motile, changes its shape very slowly, and it is possible to follow the transformation from

the tapering cylinder through the oval to the spherical form. These changes, in a specimen of fresh blood, will take place in from twenty-four to forty-eight hours; but in blood taken from the bodies of patients who have died of the disease, within two or three hours of death, they occur more rapidly. The form No. 1 is by no means constant in the blood; sometimes it is entirely wanting, and Dr. Laveran on several occasions found them alone present, but in great numbers.

Form No. 2, spherical.—This is the most common form in malarial blood, and the variations of type are shown in Fig. B. The dimensions are variable, from 2 to 10-1000ths of a millimetre in diameter.

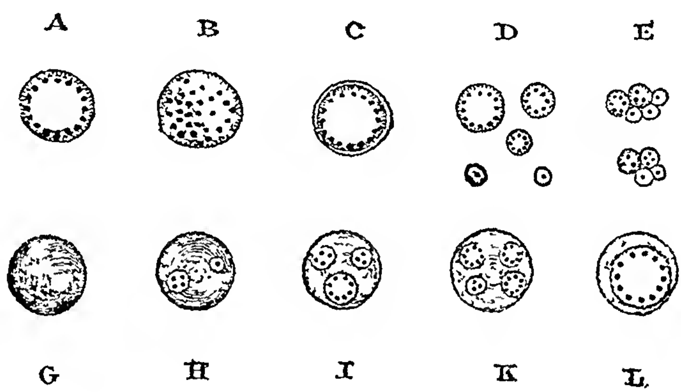


FIG. B.

A. Form No. 2, of medium size. B. Form No. 2, inclosing moving granules of pigment. C. The same form exhibiting a double contour. D. Form No. 2, small examples free and isolated. E. Similar small examples collected into groups. G, H, I, K. Red corpuscles with varying numbers of form No. 2, attached. L. Red corpuscle with one of the bodies No. 2 attached of medium size, the corpuscle is very pale.

They appear to consist of a very transparent hyaline mass, and contain granules of black or reddish pigment, identical with those found in No. 1. These granules are often regularly distributed as in A, C, D, but generally irregularly as in B. The granules exhibit a brownian movement in the larger forms.

Form No. 2 occurs free in the serum, or attached to the blood corpuscles; the smaller ones are often found in groups (E); the larger ones when attached to the corpuscles

appear to reduce the hæmoglobin to a pale zone around the spherical body as shown in No. 1, and to increase at the expense of the corpuscle which ultimately disappears. Sometimes a red corpuscle is seen with a pale spot on its surface (G), which may be taken to indicate the beginning of the attack by the parasite as yet scarcely developed. These have been observed by Marchiafava and Celli.[1]

Inasmuch as the form No. 2 is often found of the same size as a red corpuscle, the question arises, Are these bodies independent parasites or simply altered corpuscles? Dr. Richard was of this opinion for some time, but further study of these bodies convinced him that they were true parasites, and not altered blood corpuscles.[2]

Form No. 2 exhibits no nucleus in the fresh state, and even when stained Dr. Laveran has been unable to discover one; he relies on this fact as a means of distinguishing between these bodies and the leucocytes.

Motile filaments.—On carefully examining these spherical bodies it is possible to observe on the margins of some of them, motile filaments of considerable length, often three or four times the diameter of a red corpuscle, but so fine and transparent that it is difficult to distinguish them clearly. The extremities of these filaments are often slightly enlarged, their number is variable, there may be only two attached to one parasite, or as many as six. Their movements are very rapid and difficult to follow, but are of sufficient force to give a movement of translation to the spherical bodies from which they proceed. The bodies themselves are capable of certain amœboid movements and changes of form (Figs. C and D), which according to Dr. Laveran are distinct from the movements of the filaments. The pigment granules sometimes exhibit movements similar to those already described as occurring in Form 2. The filaments frequently detach themselves from the bodies to which they are attached, and Dr. Richard has described these free filaments as being sometimes so numerous that the blood appears to be literally alive with them.[3]

[1] *Gazz. degli Ospitali*, 1883, No. 66. [2] *Revue Scientifique*, 1883, p. 114.
[3] *Revue Scientifique*, 1883, p. 115.

Form No. 3.—These are small masses of hyaline matter inclosing pigment granules of very variable arrangement. There are several fairly distinct types of this form, *e.g.*

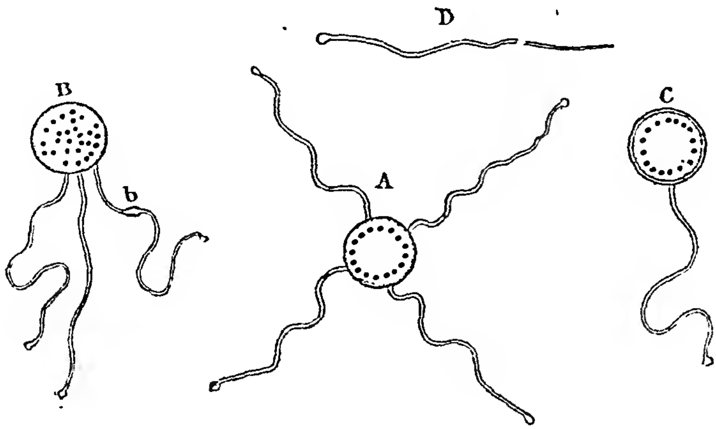


FIG. C.

A. Form No. 2, with four motile filaments. B. Another with three filaments, one of which shows a slight enlargement (b), the pigment granules in this specimen exhibited movements. C. Another with only one motile filament. D. Free motile filament. (Mag. 1000 diameter.)

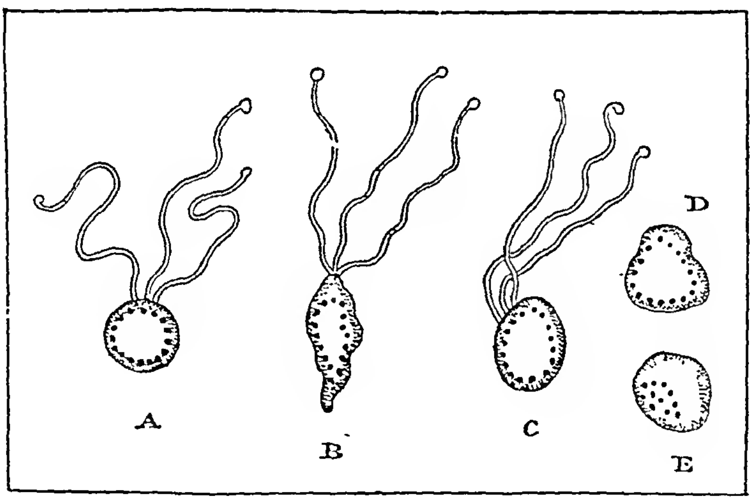


FIG. D.

A. Form No. 2, with three motile filaments as seen at 3 P.M. on December 1st, 1880. B. The same at 3.15 P.M. C. The same at 3.30 P.M. D. The same at 3.35 P.M., motile filaments disappeared. E. The same as seen at 8.30 A.M. on December 2nd, 1880. (Mag. about 1000 diameters.)

(1) more or less spherical as A, Fig. E. (2) Altogether irregular with irregular distribution of the pigment granules as B and C, Fig. E. (3) Spherical with the granules

gathered together at the centre to form one large mass. (4) Similar to (3) but with an appearance of segmentation in the central pigmented area.

A B C D E

FIG. E.

A, B, C, Types of form No. 3. D, E. Pigmented leucocytes. (Mag. about 1000 diameters)

Form No. 3. has the same dimensions as the white corpuscles of the blood, but may be distinguished from them by being more refractile and by the absence of a nucleus. Dr. Laveran is satisfied that form No. 3, is only the final stage of Nos. 1 and 2. The blood of patients suffering from malarial fever contains in addition to the bodies described, free pigment granules and leucocytes containing similar particles, sometimes only one or two, sometimes a large number. These free pigment granules and pigmented leucocytes are especially plentiful in the spleen and, in Dr. Laveran's opinion, derive their pigment from the other bodies which are destroyed or die, and whose pigment is set free in the serum, and, whilst admitting the difficulty of proof, he regards them as true parasites, and not as altered white corpuscles.

The following table shows the frequency of occurrence of the different forms as observed by Dr. Laveran :—

		Before Fever.	During Fever.	After Fever.
Form No. 1 only	43	3	18	22
Form No. 2 only	266	28	168	68
Forms 1 and 2	31	6	13	15
Form No. 2 with motile filaments	59	34	53	17
Form No. 1 and No. 2 with motile filaments	33	8	10	2
Form No. 3	—	0	11	17
Negative results	—	0	13	23
		79	286	164

Under treatment with quinine form No. 2, and those with motile filaments are the first to disappear; form No. 1 resists

rather longer, whilst form No. 3 and the pigment bearing leucocytes remain when all others have disappeared, they are also found after death. Dr. Laveran considers this as further evidence that No. 3 is the final stage of the parasite previous to dissolution, and he points out the importance of examining the blood of patients who have not been treated with quinine, when it is desired to study these bodies, as the drug has a very great effect in diminishing their number. He regards the various forms as stages in the development of one and the same organism, and the pigment granules as the product of the destruction of the red corpuscles, the movements exhibited by the granules being explained by the movement of the organism and its surroundings. As to the nature of the parasite, Dr. Laveran is of opinion that it is one of the protozoa and proposes for it the name *Oscillaria malariæ.* He further states as the result of careful comparison made in Rome, between this organism and the *Bacillus malariæ* of Klebs and Tommasi-Crudeli, that the *Oscillaria* has no resemblance whatever to the *bacillus,* and is entirely distinct from it in every way, occupying a much higher place in the animal kingdom.

The observations of Laveran were confirmed by Richard,* and there is no longer room for doubt that the blood in some cases of malarial fever exhibits changes, especially in the red corpuscles, which are accompanied by the appearance in it of certain amœboid bodies differing in some respects from white corpuscles. It is, however, to the more detailed studies of the Italian observers, Marchiafava, Celli, and Guarnieri that the general interest in these bodies is due, and the evidence on which these authors claim to have discovered the cause of malarial fever in a pathogenic organism will now require our attention.

Regarding melanæmia as *the* characteristic feature of malarial disease, these authors have carefully studied the blood in intermittent fever, with the object of elucidating the nature and mode of origin of the pigment granules. The results of these researches down to the end of the year 1885

* *Comptes Rendus,* 1882.

are thus summarised by Drs. Marchiafava and Celli.* These conclusions are a summary of results published in *Annali di Agricoltura*, 1885, Nos. 96 and 104; *Fortschritte der Medicin*, 1885, Nos. 11 and 24; and in the *Archivio per le Scienze Mediche*, 1885, No. 15, and 1886, No. 9.

"1. In the interior of the red corpuscles of the blood of patients suffering from acute malaria corpuscles are commonly found consisting of a mass of homogeneous protoplasm, which stains readily, and is endowed with active amœboid movement. We propose to name these the *Plasmodia* of malaria.

"2. In these corpuscles there is commonly found a black pigment which forms no integral part of them, but is the product of the transformation of the hæmoglobin into melanine. This transformation takes place in the interior of the red corpuscles in which these corpuscles (plasmodia) are inclosed. The pigment is not, however, constantly present; and the melanine may be absolutely wanting, even in a case of very grave malaria.

"3. These corpuscles, by a process of segmentation, resolve themselves into an agglomeration of young corpuscles, which, although devoid of amœboid movement, may, after staining, be recognised as identical with the non-pigmented corpuscles contained in the red corpuscles of the blood. This segmentation has been observed in the pigmented plasmodia which have completely invaded a red corpuscle, or in which the invasion is only partial, as well as in those which are not pigmented (cerebral capillaries). It is probable that this segmentation represents the mode of multiplication of the plasmodia in the human body.

"4. The malarial infection is transmissible to man; this is proved, not only by the clinical phenomena, but also by the fact that these non-pigmented corpuscles, capable of amœboid movement, may be found in the blood of the person inoculated. These latter, as in all other fevers, increase gradually in the blood of the person inoculated in proportion as the disease progresses; they diminish rapidly in number, issue from the red corpuscles, and disappear entirely under the action of

* *Archives Italiennes de Biologie*, tom. ix. pp. 28, 29.

specific remedies, and also when the disease terminates naturally. Nothing else has been discovered in the blood, when studied either in the fresh state or after the use of the most various methods of staining. Cultures of malarial blood made in every variety of nutritive material have yielded negative results, even when small quantities (of the same blood) have produced malaria in man. All the animals on which inoculation experiments were made appeared to be incapable of receiving the infection in this manner. The motile filaments of Laveran were very rarely met with, and were entirely wanting in all cases of pernicious malarial infection, and could at the most be considered as the protoplasmic prolongations representing the flagella of the pigmented bodies. These latter, we have said, should be considered as masses of pigmented protoplasm and not as cysts. In addition to the forms above indicated we have described others consisting of a hyaline pigmented substance possessed of a nucleus of very faint outline, and possessed of the power of very active undulatory movement.

"The preceding statements may be recapitulated and summed up as follows:—The fundamental fact of malarial infection is the existence in the red corpuscles of small protoplasmic particles capable of very active amœboid movement, which increase in size at the expense of the red corpuscle to which they have attached themselves. and the hæmoglobin of which they convert into melanine. The pigment, if there be any, is collected at the centre of the corpuscle, and these (protoplasmic) particles resolve themselves by a process of segmentation into others which represent a new generation of parasites. The analogy which exists between these bodies and certain of the protista is such that one can hardly hesitate to formulate the hypothesis that the plasmodia are parasitic in their nature."

In the same paper (*Archives Italiennes de Biologie, loc. cit.*) Drs. Celli and Marchiafava give the following list of the principal forms which may be observed in malarial blood:—

a. Amœboid forms, endoglobular, non-pigmented.

b. Amœboid forms, endogoblular, pigmented.

c. Free pigmented forms, with or without motile filaments.

d. Semilunar pigmented forms.

e. Pigmented forms having an undulate border.

f. Pigmented forms in various stages of disintegration up to the formation of young corpuscles.

g. Non-pigmented forms in process of segmentation (cerebral capillaries).

In more recent memoirs the authors have described in great detail the structure of these bodies, and the various phases of their existence.*

They divide the stages into two groups:—

a. The amœboid or plasmodium stage.

b. The falciform corpuscle stage (Forms I., II., III., of Laveran and Richard).

AMŒBOID STAGE.

In this stage the plasmodium resides within the red corpuscle, and two phases may be recognised, the vegetative and the reproductive.

In the vegetative stage, which extends from the small non-pigmented plasmodium (Figs. 1–7, Plate XXXVII.) up to complete invasion of the red corpuscle (Fig. 1–14, Plate XXXVI.).

The authors always found these bodies divisible into two parts, an exterior, or lateral part, which stained deeply with methylene blue, and an interior part of varying position (Figs. 5, 6, 7, 8, Plate XXXVI.) which stained but slightly. These they denominate ectoplasm and endoplasm respectively. This division was first observed in the non-pigmented forms. After a time in the pigmented forms the endoplasm presents the appearance of a slightly coloured mass surrounded by a clear space (Figs. 6, 7, 8, 9, Plate XXXVI.), and in this certain more highly coloured particles show themselves which are

* *Sull' Etiologia dell' Infezione Malarica. Memoria dei Prof. A. Celli, e G. Guarnieri. Atti della R. Accademia medica di Roma,* Anno xv. vol. iv. Serie II.

considered by Celli and Marchiafava to be true nuclei; traces of these nuclei are to be seen in the non-pigmented bodies. Other clear spaces are also sometimes seen, not containing any nuclear bodies; these are considered to be vacuoles. (Figs. 9 and 10, Plate XXXVI.).

THE REPRODUCTIVE STAGE.

According to Celli and Marchiafava this stage may begin at any period in a plasmodium which is small and devoid of pigment, in one which is pigmented but has not entirely invaded the red corpuscle, or at the stage in which this latter is entirely destroyed.

Without following the whole of the details given by the authors as to the precise mode of reproduction, it will suffice to say that it appears to be of two kinds, one in which the nuclear mass breaks up into a number of smaller rounded bodies similar to the original (Fig. 11, Plate XXXVI.), and another in which the division takes place more regularly, radiating from the centre and producing a number of long fusiform bodies, the pigment being collected either at the centre or the periphery of the mass (Figs. 12 and 13, Plate XXXVI.). These fusiform bodies appear to represent a stage between the spores and the falciform bodies. The other form is shown in Fig. 14, Plate XXXVI., in which a part only segments, the remainder presenting the appearance of a finely granular pigmented mass. Fig. 15 (the same Plate) shows another form of segmentation observed in the fully developed pigmented bodies; the pigment, instead of remaining irregularly distributed or collected at the centre, arranges itself in a number of small circles, the protoplasm of the plasmodium dividing in the same manner. From the periphery of a plasmodium thus segmented small, rounded, pigmented corpuscles are detached; similar small masses of protoplasm are sometimes broken off from the plasmodium in which the pigment is irregularly distributed. These small corpuscles often exhibit a filamentous prolongation which may or may

not be a true flagellum. Drs. Celli and Marchiafava have not however determined whether they are in all cases the result of a true spore formation or only of the breaking up of a pigmented plasmodium; it would further appear that multiplication by simple fission occurs in some cases. As a result of this segmentation a number of small corpuscles, pigmented or not, as the case may be, are set free in the blood.

FALCIFORM BODIES.

These present various phases which may be classed as (*a*) semilunar or falciform; (*b*) navicular or fusiform; (*c*) ovoid or rounded; (*d*) flagellate. They are identical with the bodies described by Laveran as being more or less abundant in the blood of patients who had become very anæmic as the result of repeated attacks of the disease. Laveran's Form No. I. corresponds to the falciform and navicular stage; Form No. II. to the rounded and flagellate phases; whilst Celli and Guarnieri agree with Laveran that his Form No. III. represents the dead remains of these.

These falciform and flagellate forms, according to Celli and Guarnieri, are more common in autumnal fevers, *i.e.*, relapses, than in those of first infection occurring in the summer. "Never alone, but always accompanied, before the administration of quinine, by the unpigmented amœboid forms which are more common and, diagnostically, more important."

Celli and Marchiafava have shown, and Osler has confirmed the fact, that these forms pass through their early stages *within* the red corpuscles (see Figs. 18, 19, 20, Plate XXXVI.; compare also Laveran's Fig. (*b*), p. 304).

These falciform bodies generally present a double contour (see Figs. 18–23, Plate XXXVI.). Their extremities are sometimes clear and bright, and, according to Celli and Guarnieri, they never exhibit amœboid movements, but at most a slight change of contour. The pigment is collected at the centre and, in all the phases except the last, is motionless, whereas the amœboid forms never have a double contour

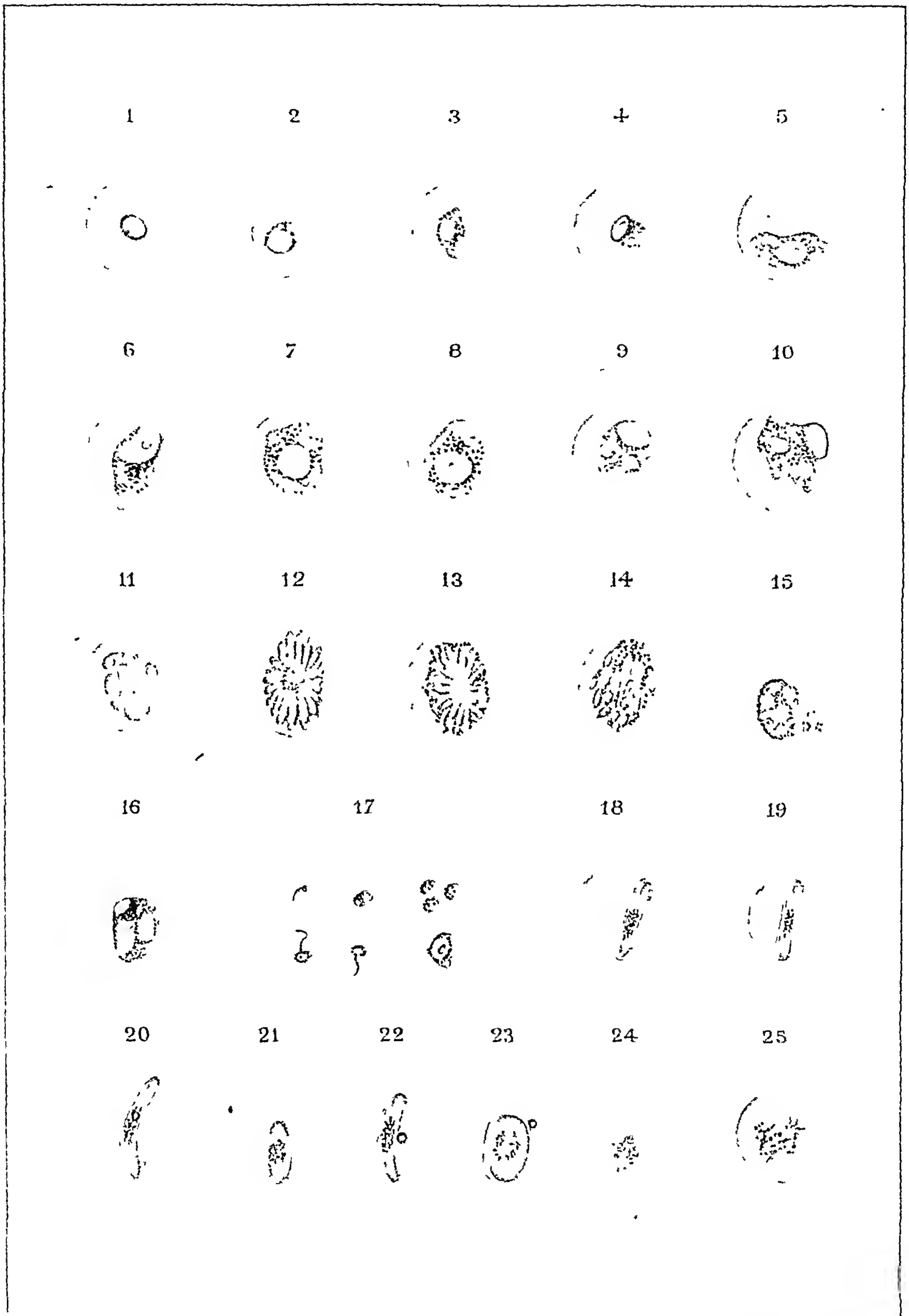


Plate illustrating the researches of Drs. Celli and Guarnieri on the *Plasmodium malariæ*.

and in them the pigment is irregularly distributed, and the subject of active Brownian movements. In specimens of these falciform bodies, coloured in the usual manner with methylene blue, there is frequently to be observed a small *rounded corpuscle close to the mass of pigment (see Figs.* 20, 21, 22, 23, Plate XXXVI.).[1]

Celli and Guarnieri state that in summer at ordinary temperatures, or by the use of the warm stage, they have been able to watch the development of the oval form from the fusiform through the rounded pigmented form to the flagellate, this last appearing to arise by a process somewhat resembling gemmation. The Italian observers are in accord with Laveran, Councilman, and Chenzinsky as to the action of quinine on the plasmodia; the amœboid forms only are affected as a rule, the falciform bodies but rarely. Three cases are given in support of this, with the results of periodic examination of the blood, in the memoir already quoted, p. 20.[2]

They are also strongly of opinion that the assertion of Laveran, repeated by Councilman, that the flagellate forms are the most important, is wrong, and attribute it to insufficient observation, and especially to insufficiently prolonged observation of the same specimens of blood.

In a late memoir by Drs. Celli and Marchiafava on the malaria fevers prevailing in Rome in the summer and autumn[3] the authors reiterate a statement made by them in 1885 that in order to study the changes which take place in the blood in malarial fever it is necessary to have under observation a large number of cases of every type and degree of intensity, and to examine the blood at every stage. They formulate as an established fact that "the malarial infection is produced by a parasite *sui generis* which invades the red

[1] Plate XXXVI. is from the most recently published memoir by Drs. Celli and Guarnieri, to whom I am indebted for permission to print the requisite number of copies for this work from the original stones.—W. N.

[2] *Sull' Etiologia dell' Infezione Malarica, Celli e Guarnieri, Roma*, 1888.

[3] *Sulle febbri malariche predominanti nell' estate e nell' autunno in Roma, Memoria di A. Celli ed E. Marchiafava. Atti della R. Accademia Medica di Roma*, Anno xvi. vol. v. Serie II.

corpuscles, lives within them, and is developed at the expense of their substance, converting their hæmoglobin into melanine, and which multiplies by fission."

Professor Golgi has studied the organisms found in the blood of malarial patients in the neighbourhood of Pavia, and believes that he has discovered that the morphological and biological characters of the parasite of the quartan type differ from those of the tertian. The Italian observers continuing their investigations on the blood of patients admitted to the Roman hospitals have also come to the conclusion that there are differences of type more or less characteristic of the season of the year, and that these differences obtain especially between the types of fever prevailing in spring and those met with in the summer and autumn.

The fevers of spring have generally a well-defined period, do not tend to assume the pernicious type, and yield readily to remedies; those of the summer and autumn are less definitely periodic, tend to assume the continuous type, are much more difficult of cure, frequently relapse and are often followed by grave anæmia; the temperature is not uncommonly subnormal. In these cases the organisms found are always the small plasmodia, and the authors give the following as the result of careful and consecutive study of the blood. During the height of the fever a larger or smaller number of the red corpuscles are found to contain one or more plasmodia in a state of active amœboid movement; the same condition holds for the sweating stage and during the first hours of apyrexia, but an hour or two before the commencement of the second attack the parasites present certain changes as follows:—

a. Round motionless forms, smaller than those referred to above, containing a minute particle of hæmoglobin in the centre (annular forms), or minute pigment granules, or both; the particles of hæmoglobin may be seen under the microscope to gradually blacken.

b. Amœboid forms relatively very small, in more or less active movement, having a dentated outline, a greyish white colour, and containing exceedingly minute particles of

pigment which require very careful observation in order to make them out.

c. Round motionless forms, of a whitish colour, larger than the former, with small rounded masses of pigment at the centre or near the periphery; frequently the whole of the remaining hæmoglobin of the corpuscle is gathered round the parasite, rendering the rest of the stroma colourless. All these forms, and especially the last three, are frequently seen at the beginning of the attack, intermingled with red corpuscles reduced to one-third of their natural size, irregular in shape and of a dark yellow colour, resembling that of old brass.*

In these fevers it is very rarely that the forms showing the process of spore formation are to be seen in blood taken from the finger, whilst they may be readily found in the types with well-marked intermittence such as quartan and tertian, especially at the beginning of the fever. When the fever has well begun, or, better, when it has lasted for a few hours, the amœboid forms without pigment may be seen.

Referring to some observations made by Professor Golgi as to the existence of certain differences in the organisms in different types of the disease Drs. Celli and Marchiafava think that they may be explained by the fact that in fevers of perfect periodicity the whole of the life processes of the parasite may be readily observed in blood taken from the finger or other part of the surface of the body, whereas in the more continuous and graver types these processes occur chiefly in the blood of the organs, and are only to be observed *post-mortem* or by operation. They are further of opinion that in the fevers of summer and autumn the parasite completes its cycle in a very short time, whereas in the typically remittent and intermittent forms the cycle is barely complete in twenty-four hours. During the half of this time the parasite remains in the unpigmented, amœboid stage, the spore formation appearing to take place in certain organs, and so rapidly that the separation of the new brood takes

* Drs. Celli and Marchiafava have called these "globuli rossi ottonati," from "ottone," the Italian word for brass.

place before they emerge, so that they are rarely seen in blood taken from the surface, and then only when the number of parasites is very great. With regard to the semilunar bodies, which have been described by Laveran, Councilman, Osler and Golgi, Drs. Celli and Marchiafava state that at first they had some difficulty in finding them, and in those cases in which they were observed were unable to trace a definite connection between them and the other forms; but from a number of observations made in the year 1889 they find reason for believing that they are a development of the plasmodia. They agree with other observers in stating that these falciform bodies resist the action of quinine, and regard it as possible that it is this form of the parasite which survives in the body of the patient and keeps alive the infection.

The difficulty with regard to these semilunar forms appears to be considerable; in a number of cases investigated by Drs. Celli and Marchiafava they failed entirely to find them in the blood taken from the finger, and, even in some cases, in the blood of the spleen taken during life. In certain cases of obstinate relapse they were found in very small numbers. In one case in which they were wanting entirely in the blood taken from the finger they were found after the fever had been cut short by quinine; in other cases in which they were wanting during life, they were found in large numbers in the organs after death. In a number of cases examined by Dr. Bignami it was found, *post-mortem*, that the falciform bodies were more numerous in the blood of the spleen and in the marrow of the bones than in other parts, but not exhibiting any process of spore formation, whilst in the capillaries of the brain and lungs the usual spore formation in the amœboid forms was easily observed. According to Laveran, these falciform bodies are chiefly to be found in those cases which have relapsed frequently and in which the anæmia is pronounced. Drs. Celli and Marchiafava, whilst agreeing in the main with this statement, find that they do occur in certain grave cases, but are unable to determine their precise relation to the disease.

They conclude, as the result of their investigations on the

fevers which have come under their notice in certain years, with regard especially to those which have at least the quotidian type, and are characterised by a tendency to a shortening of the intervals of apyrexia (and consequently to the continuous and pernicious forms of the disease), that in these types of malaria the organisms found in the blood are small amœboid plasmodia, without pigment, passing through their various stages within the red corpuscles, and that the falciform bodies are chiefly found in cases of relapse. They are of opinion that from every point of view, endemiological and clinical, and even if the disease be considered to be the result of the operation of a pathogenic organism, these various types are to be regarded as degrees of one and the same malady, in the same sense that varying degrees of intensity are recognised in any infectious disorder.

Further, in the spring fevers of Rome and in those of early summer, as well as in those forms of the disease which are common in all countries which are not gravely afflicted by malaria, the parasites are, as a rule, the larger pigmented forms described by Golgi, and regarded by him as specially characteristic of the tertian and quartan types; that is to say, season of the year and varying intensity of the infection produce modifications in the form of the parasite.

The researches of the Italian observers may be taken as confirming and extending those of Laveran, and there can be but little doubt, though there have been grave differences of opinion as to matters of detail and as to the interpretation to be put upon the results obtained, that the observations made relate to the same facts, and that the occurrence of certain more or less definite changes in the red corpuscles in some cases of malarial fever must be regarded as established. The reader will not have failed to notice that whereas the organism described by Klebs and Tommasi-Crudeli is a bacillus, that of Celli, Marchiafava, Guarnieri, Golgi, Osler, Councilman, and others holds a different position in the scale of life, and morphologically is essentially different. This difficulty has attracted the attention of more than one observer, and Dr. Schiavuzzi, of Pola, has endeavoured to

Explanation of Plate XXXVII.

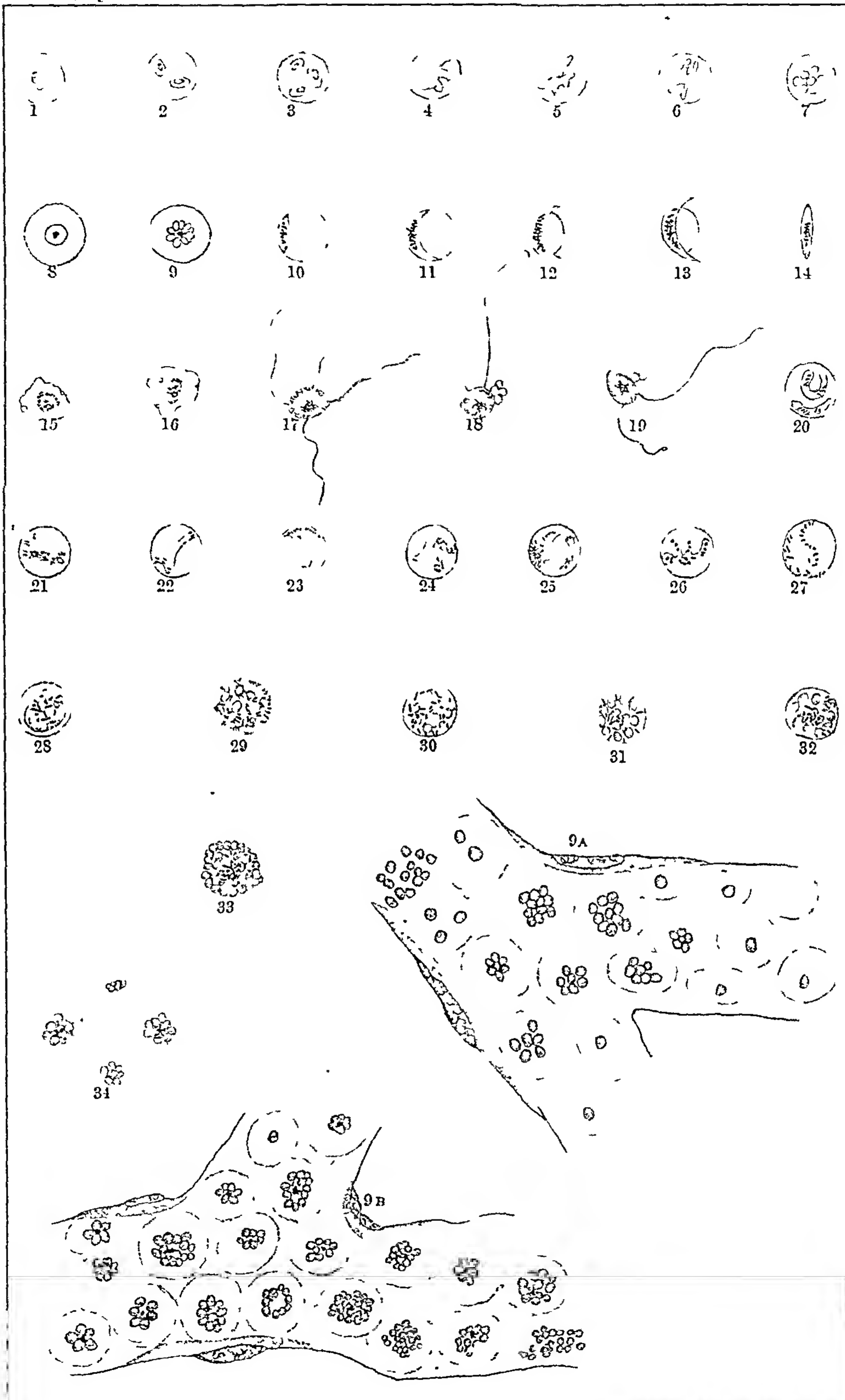
This plate is intended to illustrate the present position of the investigations of the Roman observers. The figures have been selected by Dr. A. Celli from various papers published by himself and his colleagues on the subject.

Figs. 1–9 are the forms most commonly met with in the types of fever prevailing in summer and autumn, and also in the pernicious forms of the disease.

Figs. 9A and 9B are drawings of cerebral capillaries showing the altered corpuscles *in situ*.

Figs. 10–19 show the various modifications of the semilunar bodies and morphological details which have been described by Laveran, but, according to Drs. Celli and Marchiafava, incorrectly interpreted by him.

Figs. 20–34 illustrate the forms which are found in cases of periodic fever of well-marked type, such as quotidian, tertian, &c.



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reconcile the apparent discrepancy between the *bacillus malariæ*, and the *plasmodium*. In a paper * published in the *Beiträge zur Biologie der Pflanzen* (Cohn) he gives an account of his researches on the subject, of which the following is a brief *résumé*.

Dr. Schiavuzzi studied the organisms of the air in the neighbourhood of Pola, and obtained a bacillus having a very close resemblance to that described by Klebs and Tommasi-Crudeli, *loc. cit.* This he cultivated and obtained free from other organisms, and infected a number of rabbits by means of subcutaneous injection. The temperature curves of the animals operated upon show a certain rhythmic variation, having some analogy to the curve of quotidian ague, but with irregularities which more or less destroy the value of the comparison; in some of the cases given an abscess formed at the point of injection. The organisms were found to have multiplied in the blood, the spleen was in some cases slightly enlarged, and there was some evidence of the formation of black pigment. Further, Dr. Schiavuzzi states that he was able to observe changes in the red corpuscles similar to those described by Celli and Marchiafava.

The results of these observations were submitted to Professor Tommasi-Crudeli, and by him communicated to the Accademia dei Lincei in December, 1886, and are summed up by him as follows:—

"1. The constant presence of a bacillus, morphologically identical with that described by Klebs and myself under the name of *bacillus malariæ*, in the malarial atmosphere of Pola, and the absence of it in non-malarious localities, is proved by the researches of Dr. Schiavuzzi.

"2. Pure cultures of this bacillus injected into rabbits produce a fever possessing all the clinical and anatomical characteristics of malaria.

"3. When the blood, spleen, and abdominal lymphatic glands of the affected rabbits are subjected to conditions favourable to the development of this organism, it is possible

* *Beiträge zur Biologie der Pflanzen* (Dr. Ferd. Cohn), Bd. v. Ste. 245—288. *Untersuchungen über die Malaria in Pola von Dr. Bernardo Schiavuzzi in Pola.*

Description of Plate XXXVIII.*

Figs. 1–3. Photographs of the *bacillus malariæ*, made in Breslau by F. Schmidt from preparations made by Dr. Schiavuzzi in Pola. Mag. 1 ; 1000.

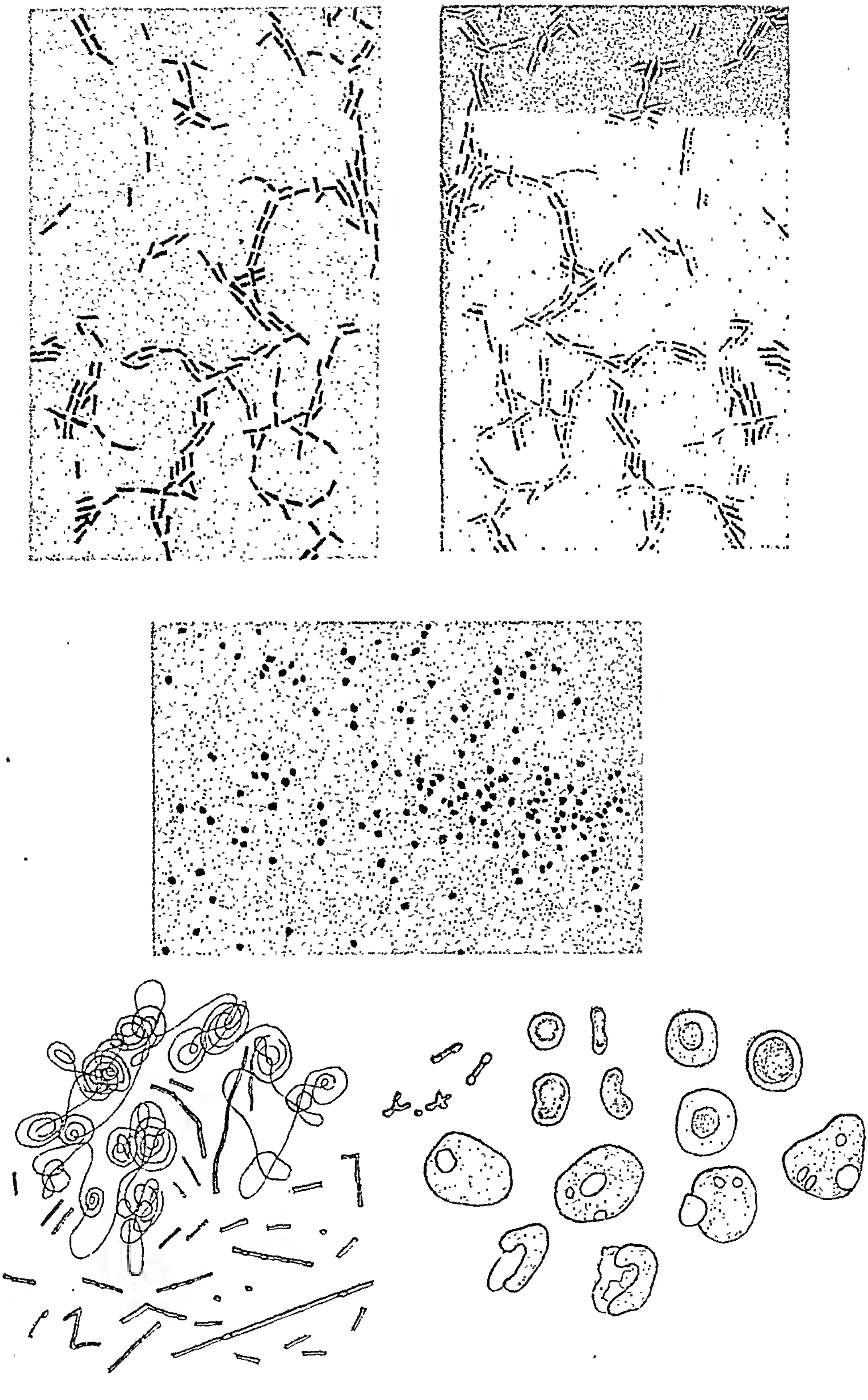
Fig. 1 on light ground ; Fig. 2 on dark ground.

Fig. 3. Spores of *bacillus malariæ* cultivated on agar-agar in the summer of 1887.

Fig. 4. Development of the *bacillus malariæ* drawn from specimens obtained from the same cultures as No. 3. The bacillus forms on agar-agar a thin, spreading, grayish white film ; the rods, which in part develop into long threads, remain sterile at low temperatures ; at temperatures above 30° C. a large number of oval highly refractile spores develop in the middle of the rods. When the rods are arranged in chains the spores are found in larger or smaller number along their course. When the process of development is arrested the threads become serpentine and twisted around one another in wavy knots. After a time the threads break up and set free the spores as shown in Fig. 4. The bacillus liquefies the gelatine on which it is cultivated, forming a layer of about two millimetres in thickness.

Fig. 5. Changes in the blood corpuscles of a rabbit injected with the bacillus malariæ. In the serum of the blood there are a number of small bacilli (*a*) and other bodies (*b*). Besides the normal blood corpuscles, others are seen which are deformed and have lost a portion of their contents. On staining with methylene blue, corpuscles are seen which contain within their substance highly refractile, deeply stained discs of variable size (*d*). In other preparations the red corpuscles have taken on a peculiar form (*e*), the protoplasm forming a curious plasmodium-like mass which sometimes has the appearance of a disc, sometimes of a biscuit, and which appears to emerge from the corpuscle.

* This plate is inserted at the suggestion of Professor Tommasi-Crudeli, and with the permission of Drs. Schiavuzzi and Ferd. Cohn. It is a photographic reproduction of the plate published with Dr. Schiavuzzi's paper, *loc. cit.*



Figures to illustrate Prof. Schiavuzzi's observations on the Bacillus Malariae

to obtain a more or less abundant growth of a bacillus morphologically identical with that which set up the symptoms in the animal.

"4. In animals which have been poisoned with pure cultures of this bacillus the red blood corpuscles exhibit certain changes which Celli and Marchiafava have described as characteristic of malaria. This serves as a confirmation of what I said in my last communication to the Academy (sitting of May 2, 1886), namely, that these changes in the blood corpuscles are not due to the development in them of an animal parasite (which thus far no one has been able to discover, either in the air or in malarious localities), but that on the contrary it is the effect of the degeneration of the red corpuscles due to the direct or indirect operation of a disease-producing ferment of an entirely different nature."

Admitting that the organism described by Klebs and Tommasi-Crudeli is the specific cause of malarial fever, this is of course the only explanation possible.

In an address delivered before the Pathological Society of Philadelphia,* Professor Osler described the results of his own observations on the blood of malarious patients, and the organisms found therein. He agrees in all material points with the observations of Laveran, Celli, and Marchiafava. Out of seventy cases examined he failed to find the organisms in ten, and he is of opinion that the organism has no relation to the bacilli, bacteria, and micrococci which have been found in the blood in other diseases, and he considers that it is a flagellate protozoon belonging to the order flagellata-pantostomata. Mitrophanow has suggested a new genus, *hæmatomonas*, to include the monad hæmatozoa, and Dr. Osler prefers to class this organism as genus *hæmatomonas;* species *hæmatomonas malariæ*, and he would define it as follows:—body plastic, ovoid or globose, no differentiation of protoplasm, which contains pigment grains; flagella variable from one to four. Highly polymorphic, occurring in (1) amœboid form; (2) crescents, encysted form; (3) sporocysts; (4) circular, free, pigmented bodies.

* Reported in the *British Medical Journal* of March 12, 1887.

These are the chief facts regarding the existence in the blood of malarial patients of an organism which may possibly be the specific cause of the disease. We are now in a position to consider the question, to which all that has gone before is but the prelude, namely, from what we know of the disease itself, the conditions under which it prevails, its pathology and pathological anatomy and the results of the researches into its ætiology which have been detailed, Is malaria the result of the operation of a pathogenic organism, or is it caused by the action upon the human body of those peculiar climatic conditions which have been shown to prevail in all malarious countries in a greater or less degree? To a consideration of the arguments for and against these two theories we will now address ourselves.

CHAPTER XXIII.

THE ARGUMENTS FOR AND AGAINST THE CAUSATION OF MALARIA BY A PATHOGENIC ORGANISM.

THE reader is now in possession of all the more important facts on which the supposed origin of malarial fevers in a pathogenic organism is based. We have now to examine how far the advocates of this theory have proved their case. It might appear that in dealing with a disease the phenomena of which are so simple as those of intermittent fever, there should be no great difficulty in determining whether it is, or is not, caused by an organism present in the air or soil. The distribution of the disease is so definite, and the intensity of it in certain places so great and so well known that with the present methods of research, the solution of the problem would seem to be only a question of patient investigation; yet, despite all that has been done, this is very far from being the case. There is perhaps no disease for the causation of which so many different organisms have been held responsible, or on such slender evidence; and of all the observations which have been recorded there is little difficulty in determining that those of Klebs and Tommasi-Crudeli, or Celli, Marchiafava and their colleagues, together with Schiavuzzi, are alone worthy of serious consideration. With regard to the others, the evidence in support of their claims is all of one kind, and is all pervaded by the same fallacy. In each case the observer examining the soil, air, or water of an excessively malarious locality found an organism which appeared to him to be more abundant than any other, and being found in some cases in

the blood and secretions of patients suffering from the disease, was therefore assumed to be the cause of it. In some cases the observer was attacked by fever after inhaling or otherwise absorbing the organisms into his system, and this has been advanced as additional proof, regardless of the fact that in a person who has been so thoroughly exposed to the conditions under which the disease might be acquired, as all these observers undoubtedly were, no experiment of inoculation or infection could be of the slightest value; for even if fever should follow such inoculation or other mode of infection, the very nature of the disease, and the exposure to which the individual had been subjected, would render all deductions from such experiments unsound. Such being the case we will confine ourselves to a critical examination of the researches of the last-named observers.

Professors Klebs and Tommasi-Crudeli rely upon the results of their experiments upon rabbits for proof that the bacillus isolated by them from the air and soil of the Roman Campagna is the specific cause of malarial fever, inasmuch as they succeeded in inducing in rabbits a fever which exhibited some tendency to intermission, and was accompanied in some cases by enlargement of the spleen, the bacillus being afterwards found in the blood of the animals experimented upon; whereas, in rabbits inoculated with material obtained from non-malarious localities negative results were obtained, though several of the animals in both series died from septicæmia. The objections to these experiments are numerous. Firstly, the rabbit is by no means a satisfactory animal for the observation of changes of temperature, as the variations in the normal state are very considerable and irregular, occurring without any apparently sufficient cause; secondly, the intermissions of temperature obtained were by no means so regular and definite as in a case of intermittent fever occurring in the human subject; the enlargement of the spleen is not in itself proof of the malarial character of the fever; and lastly, no special changes in the blood corpuscles appear to have been noticed. Altogether, these observations, though carried out with great care, must be regarded as very unsatisfactory,

and as by no means proving all that their authors claimed for them.

The *bacillus malariæ* and the methods used by its discoverers were submitted to a most careful and rigorous examination by Dr. Sternberg in the year 1880, by order of the National Board of Health of the United States.*

Dr. Sternberg says in his report, "It seems to me that nothing short of a paroxysmal fever, exhibiting marked periodicity as to the recurrence of the paroxysms, and a sufficient number of them to remove the suspicion of apparent periodicity from accidental causes, can be accepted as proof in an experimental investigation of this nature." "I do not find such proof in the temperature charts of Klebs and Tommasi-Crudeli, nor do I find it in my own charts, and my observations give me little confidence in changes in the dimensions of the spleen, the presence of black pigment and an increase of body weight as evidence of malarial infection in an animal which, so far as we know, is not susceptible to the influence of the malarial poison when exposed to it in the usual manner in which it manifests itself among the human inhabitants of a malarial region." Adopting the methods of Klebs and Tommasi-Crudeli, Dr. Sternberg examined the mud and air of various malarious localities in the neighbourhood of New Orleans. He found them to contain a great variety of organisms, and amongst these one which closely resembled the *bacillus malariæ*. A large number of rabbits were inoculated with these different organisms, and very varying results obtained, but, in Dr. Sternberg's opinion, nothing of the nature of true paroxysmal fever. Many of the animals died from septicæmia, and as regards the presence of black pigment in the blood and the enlargement of the spleen, Dr. Sternberg found that these undoubtedly septicæmic animals had enlarged spleens, and that their blood contained free pigment. He is therefore of opinion that the results obtained by Klebs and Tommasi-Crudeli are in no sense conclusive. Further, in order to satisfy himself as to the truth of his opinion that these results might be obtained in

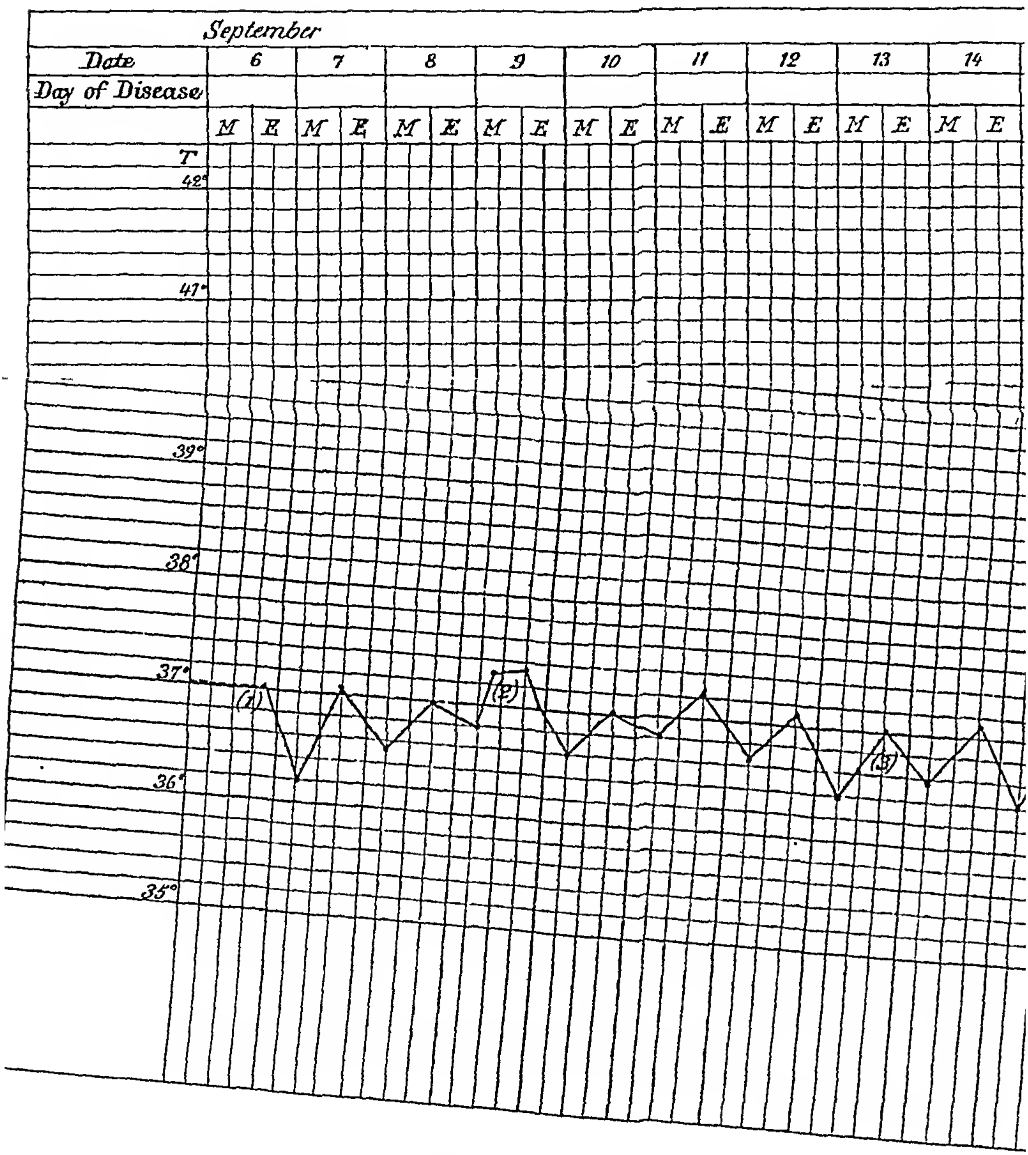
* *National Board of Health Bulletin*, Supplement, No. 14, July 23, 1881.

various ways, he inoculated rabbits with all manner of organisms obtained from the soil of malarious localities, with his own saliva, and with various other materials, and in this way showed conclusively that whatever may be the possible interpretation of the results obtained by Klebs and Tommasi-Crudeli, they did not prove that the organism described was the specific cause of malarial fever, or in Dr. Sternberg's own words:—

"Some of the organisms found in swamp-mud, in gutter-water, and in human saliva are capable of multiplying within the body of a living rabbit, and the fluids and organs containing them (blood, serum from cellular tissue, spleen, &c.) possess virulent properties. In other words, an infectious disease is produced which may be transmitted from animal to animal by inoculation. Among the organisms found upon the surface of swamp-mud, near New Orleans, and in the gutters within the city limits, are some which closely resemble and perhaps are identical with the *bacillus malariæ* of Klebs and Tommasi-Crudeli; but there is no satisfactory evidence that these or any other of the bacterial organisms found in such situations, when injected beneath the skin of a rabbit, give rise to a malarial fever corresponding to the ordinary paludal fevers to which man is subject.

"The evidence upon which Klebs and Tommasi-Crudeli have based their claim to the discovery of the *bacillus malariæ* cannot be accepted as sufficient: (*a*) because in their experiments, and in my own, the temperature curve in the rabbits operated upon has in no case exhibited a marked and distinctive paroxysmal character; (*b*) because healthy rabbits sometimes exhibit diurnal variations of temperature (resulting apparently from changes in the external temperature), as marked as those shown in their charts; (*c*) because changes in the spleen such as they describe are not evidence of death from malarial fever, inasmuch as similar changes occur in the spleens of rabbits dead from septicæmia, produced by the subcutaneous injection of human saliva; (*d*) because the presence of dark-coloured pigment in the spleen cannot be taken as evidence of death from malarial fever, inasmuch as

To face p. 329



(1) 1st Injection of Malarial Blood.
(2) 2nd ,, ,, ,, ,,
(3) 3rd ,, ,, ,, ,,

this is frequently found in the spleen of septicæmic rabbits" (*l.c.*, p. 10).

The next phase of the inquiry is marked by the discovery in the blood of the altered corpuscles and other bodies described by Laveran, and the confirmation and extension of Laveran's work by the researches of Celli, Marchiafava, and their colleagues. We have already seen the exact nature of their discoveries and the interpretation placed upon them by the authors. Comparing this more recent work with that of Klebs and Tommasi-Crudeli, we find ourselves at once confronted by a somewhat serious difficulty; the *Plasmodium malariæ* is clearly *not* identical with the *bacillus malariæ*, belonging, as it must, to an entirely different group in the animal kingdom, that is to say, if the organism described by Celli and Marchiafava *be* an organism, the *bacillus malariæ* must give place to it.

According to Professor Crudeli (see page 321) this difficulty is solved by the researches of Dr. Schiavuzzi (*loc. cit.*) who, whilst as it were re-discovering the *bacillus malariæ*, has observed in animals inoculated with it, the same changes in the blood corpuscles described by Laveran, Celli and Marchiafava, and Professor Crudeli regards these changes in the corpuscles as the result of the operation of his bacillus. Celli and Marchiafava, though they have failed in their attempts to isolate their *plasmodium malariæ* and to cultivate it outside the body, have made a number of experiments upon the human subject as to the transmissibility of the disease by inoculation with blood containing these bodies; many of the results were negative, but they have published * the temperature curve (Plate XXXIX.) obtained in one of these experiments.

That certain remarkable changes do take place in the blood in some cases of malarial fever must now be regarded as beyond doubt, and it is somewhat curious that whilst the *bacillus malariæ* has only been found in the air and soil, the *plasmodium malariæ* has as yet only been found in the blood, and has thus far resisted all attempts to cultivate it outside

* *Fortschritte der Med.*

the body. In the author's opinion, Professor Crudeli's explanation is most unsatisfactory, and will require a very large amount of experimental research in its support before it can be regarded as having any claim to consideration, especially after the researches of Sternberg on the *bacillus malariæ*, which at least throw a very grave doubt upon its existence as a specific organism.

Thus the whole question of the origin of malarial fever in a pathogenic organism is still very far indeed from being settled, and the only real addition to our knowledge of the subject consists in the discovery of these changes in the red corpuscles, for the proof that the *plasmodium malariæ* is a distinct organism is still wanting.

Koch has laid down the following conditions as essential for proving the existence of a pathogenic organism:—

1. The micro-organism must be found in the blood, lymph, or diseased tissues of man or of animals suffering from the disease or dead from it.

2. The micro-organisms must be isolated from the blood, lymph, or tissues, and cultivated in suitable media outside the animal body. These pure cultivations must be carried on through successive generations of the organism.

3. A pure cultivation thus obtained must, when introduced into the body of a healthy animal, produce the disease in question.

4. Lastly, in the inoculated animal the same micro-organism must again be found.

It is generally admitted that until these conditions have been satisfied, it cannot be said that the existence of a pathogenic organism has been proved, and it cannot be said that in the case of the micro-organisms of malaria any one of these conditions has been satisfactorily fulfilled. Organisms, or bodies supposed to be organisms, have been found in the blood of patients suffering from the disease, but they have not been cultivated outside the body. Others have been found in the air and soil, but it is more than doubtful whether the symptoms produced by them when introduced into healthy animals were malarial, or bore any relation to malarial fever.

The experiments of Celli and Marchiafava on the transmissibility of the disease from one person to another by inoculation are of very doubtful value, for it has already been pointed out that experiments of this kind made in a malarious country upon persons who have spent their lives in that country, though so far as they may be aware, they have never suffered from the disease, are eminently unsatisfactory; for it is a well recognized fact that in all countries in which these fevers prevail their onset may be determined by a number of circumstances which are not of the nature of infection in any sense whatever. Cases of other febrile disorders even of a trivial character occurring in malarious countries are notoriously prone to take on an intermittent type not proper to the particular disease, and intermittent fever is, or used to be, a very common result of surgical operation in such countries. Now it may be urged, and with very good reason, in explanation of these cases, that the patient, unknown to himself, had acquired the malarious habit, if such it may be called, and that the other disease, or the surgical operation, only acted in determining an access of intermittent fever in precisely the same way as it would in the case of a person known to have suffered from it on some previous occasion. These inoculation experiments are all of the nature of surgical operations, and though they be carried out with the greatest possible skill, and though every precaution possible be taken to prevent its occurrence, something of the nature of septic poisoning is only too likely to occur. When we consider that these experiments have always been carried out upon persons who have lived in a malarious country, who, whether they know it or no, may possibly have acquired the disease or habit, though it has remained dormant in their bodies, no results obtained, however apparently characteristic the temperature curves may be, can be regarded as satisfactorily proving the transmissibility of the disease from one individual to another. As a matter of fact, not all such experiments have succeeded nor even a large percentage of them. It is true that only a small number have been made, but the objections to them are so obvious that until it can be shown that persons who have never lived

in a malarious country, and who consequently can never have acquired the disease, may be infected with it by inoculation, such inoculation to be carried out in a place where malaria is unknown, no inference can be drawn from the results of such experiments.

The failure of these inoculation experiments has, however, a certain significance in itself. If malaria be caused by a pathogenic organism, that organism must exist in the air or soil, or both, of malarious localities, and therefore animals inoculated with such organisms as are to be found in the air or soil should, in some cases at least, acquire the disease. The intensity of the fever in certain localities is such that it seems hardly possible, granting the existence of such an organism, but that out of a large number of experiments some should yield a positive result. In the year 1873, Griffini carried out a lengthy research on the effect of the intravenous injection of the dew collected in malarious localities upon dogs and rabbits. He found that the temperature rose to a variable degree after the injection, and that the fever passed away and did not return; that is to say, his results were entirely negative. Objection may be taken to these experiments, inasmuch as it is somewhat doubtful whether either the dog or rabbit is susceptible to the disease, and there is no doubt but that the crucial experiment should be made upon the human subject. This has been done by Professor Silvestrini.* He began by observing the effect of the subcutaneous injection of dew, collected in certain very unhealthy localities in Sardinia, upon dogs and rabbits, and failing to obtain any rise of temperature whatever in these animals, he experimented upon the human subject. In five cases he injected fresh serum of blood taken from a patient suffering from a grave attack of fever; the result was in all cases absolutely negative. No less than fifty-two other individuals were then experimented upon by the injection of dew and the washings of soils from well-known malarious places; and, though the material, when seen under the microscope, was teeming with organisms of various kinds, the only result

* *La Malaria*, Parma, 1885, pp. 169—206.

obtained was in three or four cases the production of abscess at the point of injection and the slight fever which might be expected to ensue; none of the subjects of experiment exhibited the slightest tendency to the development of anything resembling intermittent fever, although many of them were but recently recovered from the disease. Negative evidence is undoubtedly to some extent unsatisfactory, but as neither Klebs and Crudeli nor Schiavuzzi appear to have experienced any difficulty in obtaining specimens of the *bacillus malariæ*, it seems strange that the whole of Professor Silvestrini's experiments should have failed so completely. Look at it how we will, the whole of the evidence in favour of the bacillus of Klebs and Crudeli, as the specific cause of malarial fever, is most unsatisfactory, and we are fully justified in regarding its relation to the disease as extremely doubtful.

Next let us examine the position of the *plasmodium malariæ* of Celli and Marchiafava. Our first question must be, Is there any proof that it is a distinct organism? or should we not rather accept Professor Crudeli's view that the forms described are only profound modifications of the red corpuscles? There is yet another view which Dr. Osler appears to regard as not wholly unworthy of consideration, namely, that these bodies are parasitic hæmatozoa, having no direct relation to the disease, but occurring in malarious localities and possibly to be found in the blood of healthy individuals. That such hæmatozoa may exist in the blood of animals without apparently producing any specific malady is now well known, and before this theory can be dismissed as untenable it would be desirable to have the results of a very large number of observations on the blood of the inhabitants of malarious countries not suffering from intermittent fever. There is, however, one serious objection to this hypothesis; the researches of Celli, Marchiafava, and Guarnieri show that the connection between these organisms, altered corpuscles, or whatever they may ultimately be found to be, is exceedingly close, and in the author's opinion only two views are possible: either they are parasitic organisms directly connected with

the phenomena of the disease, or they are simply altered corpuscles.

From the writings of the Italian authorities, it might be supposed that there is little or no difficulty in observing these changes in the blood in any case of intermittent fever. Such, however, is very far from being the case; in patients suffering from the very grave forms of the disease the difficulty is certainly minimised, but in the slight attacks which do not materially interfere with the occupation of the patient, it is often impossible to discover anything abnormal in the blood; and it must be accepted as a fact that there are many cases in which the most patient investigation will fail to detect the presence of these altered corpuscles. This at least has been the author's experience in the examination of his own blood, and that of eight or ten well-marked but not severe cases which he was enabled to study, whereas, in a large number of the more severe cases under the care of Drs. Celli and Marchiafava, there was no difficulty after one or two trials in observing the changes described, or some phase of them. The occasional complete absence of these changes has been noticed by some of the American observers, and it is certainly very desirable that the constant presence or otherwise of these so-called plasmodia should be definitely determined. If the intensity of the fever bears any relation to the number of these bodies present in the blood, they should be found in all cases, and the very fact that it is often a matter of difficulty to discover them throws a certain amount of doubt on their direct connection with the disease.

Celli and Marchiafava, following up the researches of Golgi, are inclined to believe that certain forms are characteristic of certain types of fever, and that the semilunar bodies represent the quiescent stage of the parasite. The whole of the evidence on this point is, however, very small and incomplete, and does not, in the author's opinion at least, explain the changes of type or the well recognized combination of types which may occur in the same patient at the same time; still less will it explain the constant liability of the individual to a recurrence

of the disease many years after removal from a malarious climate, and under conditions which render it impossible that fresh infection should have taken place. The conditions under which ague reappears in a person who has long been free from it are very various, and the mode of reappearance is of two kinds; in the first, the individual, after years of freedom from disease of any kind and imagining himself completely cured of the ague, acquires some acute febrile disorder, the temperature curve of which exhibits the most unmistakable remissions or intermissions, which disappear when the so-called anti-periodic remedies are administered, or if not treated will disappear on the recovery of the patient from the particular disorder from which he is suffering. Such a person may perhaps never again have an attack of ague during the remainder of his life, or, as not infrequently happens, the acute disorder from which he has suffered may, as it were, revive the dormant disease, and a prolonged and obstinate ague result. This will require the same treatment as an original attack, with this difference, that it will be far more difficult of cure, and, if cured, the danger of relapse will be much greater than before. Such cases are common enough and very difficult to explain on the hypothesis of a pathogenic organism as the exciting cause of ague; nor is the difficulty diminished by the fact that many years may elapse between the original attack and the recurrence of the disease under entirely different circumstances. That an organism should remain dormant in the body for so long a period, to be ultimately roused to action by the setting up of some other disease in the body of its host, is at least very difficult of comprehension. We might possibly explain this peculiarity of malaria by supposing that the original attack, whatever its cause may be, produced some permanent effect upon the heat-regulating nervous system, of such a nature that it retains a tendency to break down under the strain produced by any febrile disorder, and so to reproduce all the phenomena of the primary disease. Such an explanation has never, so far as the author is aware, been suggested, and involves considerations which would, in his opinion, render the abandonment of the organism theory, and

the adoption of the "chill theory," or some modification of it, a more logical course to pursue.

The phenomena of intermission have been explained by the advocates of the germ theory of malaria as the result of phases in the life history of the organism; but this is apparently nothing more than an opinion, and no observations or experiments have been made which tend in any way to confirm it. There would be but little difficulty in accepting this view if there were only one type of the disease; but we must explain at least three different types—the quotidian, tertian, and quartan. Were the changes in periodicity irregular and uncertain, in fact, were the disease intermittent but not strictly periodic, we might still accept this explanation; such, however, is not the case. The hour at which an attack of any type will begin may be foretold by the patient with the greatest precision, and the tertian which develops on the subsidence of a quotidian, is as regular in its period as if it were a new disease. If by the use of drugs or other means we were interfering with phases in the life history of an organism there would be some evidence of effort on the part of such organism to re-assert itself at the earliest possible opportunity, and yet, the period will change even when no remedies whatever are used, and the interval of repose will lengthen until the quartan type is reached, when all experience tends to show that even violent remedies may prove of but little value in combating the disease, and the patient must in most cases be content to endure it until it, as it were, wears itself out. If, however, the original attack be promptly and judiciously treated, it is quickly reduced to the tertian type, and this, after one or two feeble attacks, disappears entirely. The probability of relapse in a case so treated, even when the original attack is exceedingly severe, is infinitely less than in a relatively slight attack which receives no treatment at all, or, what is still worse, has been treated by the reckless administration of quinine at all periods, and during the accesses of fever.

On the assumption that quinine kills the organisms, or at least the majority of them, it is not difficult to understand a

period of rest followed by a fresh outbreak of the same period as before, as soon as a fresh brood of organisms has developed, or even attacks of irregular period; but the perfect regularity of a tertian or quartan following on a remittent, for example, is very difficult to understand on this hypothesis.

The double and reduplicated forms present still greater difficulty, but the explanation breaks down entirely when we attempt to apply it to the compound types. We are bound to regard these as concurrent disorders, requiring the same treatment. The first effect of remedies is to destroy the type of more frequent period, or, if no remedies be used, it will disappear spontaneously, not changing the period but simply omitting one of the components of the curve. It is very difficult to understand why the general treatment should produce this result, and why, if we regard the compound disease as the result of the operation of distinct broods of organisms, it should affect one and not the other, but such is the case. It might be urged that the remedies only acted on the parasites at certain stages of their life history, but this will not explain those cases in which the quotidian and tertian attacks coincide. Quinine given just before the combined attack is due should meet both sets of organisms in the same stage, and the same dose should cure both tertian and quotidian, but unless very large doses indeed are given this does not occur, the quotidian will cease and the tertian remain to become quartan or irregular if neglected.

There is yet one more fact with regard to malaria, the significance of which has hitherto been neglected. It has been conclusively shown that the parts of the body most affected by the disease are the marrow of the bones, the spleen, and the liver; though but little is known of the mode of formation of the red corpuscles in the adult, or of their ultimate fate, all our information points to these organs and tissues as the site of such changes as do occur. If, as Professor Crudeli seems to think, the *plasmodium malariæ* is only an altered corpuscle, we have some reason for regarding the disease as essentially an interference with the hæmatopoietic

function of the body ; how caused we are not in a position to say definitely, but there would appear to be a close analogy between malaria and so-called pernicious anæmia in respect of the changes in the blood corpuscles, and it is at least possible for these changes to occur without the interference of an organism.

CHAPTER XXIV.

THE ARGUMENT FOR AND AGAINST THE CAUSATION OF MALARIA BY CLIMATIC VICISSITUDES.

IT has already been said that of all the theories advanced to account for the origin of malarial fevers two only, namely, the "germ theory" and the "chill theory," have any claim to serious consideration; neither are new, but the prevailing tendency to regard disease as the result of the action of a pathogenic organism has somewhat summarily thrust into the background a theory as to the origin and nature of malaria which, though very imperfectly stated by its originators, is deserving, in the author's opinion, of serious consideration. In discussing the nature and probable cause of any disease each and every fact connected with it must be brought under review, and no theory can be accepted which does not more or less satisfactorily explain the whole of them. The facts connected with the disease have been set out at length, and we have examined more or less minutely the position of those theories which attribute the disease to the action of a pathogenic organism; we have now to consider how far the evidence at our disposal favours or otherwise the theory that malaria has its orgin in climatic vicissitudes.

The distribution of the disease.—The distribution of malaria throughout the world points most clearly to a relation to temperature and moisture; it follows the line of the great rivers, is especially prevalent in districts liable to flood, and has been associated from time immemorial with low-lying swampy land. It has been shown that the intensity of malaria

is largely governed by the latitude of the countries in which it prevails, and that in general terms the disease diminishes in intensity from the equator to the poles. More detailed investigation, and the existence of certain obvious exceptions, proved that mere latitude was not the important factor in determining the distribution, but only latitude as influencing temperature, and that the lines of equal intensity, if they can be said to exist, more strictly coincided with the isothermal lines than with parallels of latitude.

Relation to altitude.—The relation of the disease to altitude, which is equally undoubted, has been shown to be in effect only a form of relation to temperature, and many apparent anomalies of distribution have been explained by the existence of local conditions which place the particlar locality outside the sphere of operation of a general law.

Relation to climate and season of the year.—Following this general relation to temperature into detail, we found, as we had good reason to expect, that climate and season of the year exercised a powerful influence upon the prevalence and intensity of malaria, and we learned that though in general terms the intensity of the disease throughout the world is directly proportional to the temperature, its absence in many countries where the mean temperature is excessive caused us to suspect that something beyond mere high temperature was concerned in producing or favouring the production of the disease.

This general relation to climate, together with the peculiarly local distribution of the disease, led us to consider that local climate was probably of great importance in determining the local variations in intensity shown to exist.

Relation to soil and water.—Structure and conformation of the soil and its behaviour towards water being perhaps the chief factors in determining local climate, the relation of the disease to the constitution and conformation of the soil, and to water are of obvious consequence. The result of our inquiry on these points tended to show that the intensity of the disease was more strictly proportional to the daily range of temperature, and, regarding certain examples of the existence

of malaria in localities remarkable for the more or less complete absence of water, that water favoured the production of the disease just in so far as it is a powerful agent in the production of a great diurnal range of temperature; we are therefore justified in assuming a close connection between the disease and an excessive diurnal range of temperature. Some authorities have rested content with this fact, and have assumed that the exposure of the body to these violent changes is sufficient cause for the disease. It may be urged, however, that the presence of water in the soil under a hot sun is eminently favourable to the growth of the lower forms of life, and that in describing a locality as a hot-bed of malaria, the words should be taken in their literal sense. There is one serious objection to be raised to this, namely, that in the instances cited of the prevalence of intense fever in places where water is unobtainable, and where the soil can hardly be said to exist at all, the conditions cannot be regarded as favourable to the growth of organisms, certainly not of those organisms which flourish in the swamps of the plain, whereas the diurnal range of temperature is even more marked than in those localities where the soil is more or less soaked with water; that is to say, the condition required by one theory remains, whilst those required by the other have disappeared. The fever produced is the same in both cases, but the only factor equally present in a steaming swamp and a sun-baked granite rock, destitute of soil, water, and vegetation, is the great diurnal range of temperature. Conversely, in non-malarious countries we do not find these sudden and violent changes; the range of temperature may be very considerable in itself, but it is relatively small, and the rate of rise and fall is practically constant throughout the whole twenty-four hours. There is thus no escape from the conclusion that violent changes of temperature, if not the direct cause of the disease, are prime factors in its production. Professor Tacchini has, as we have seen, brought the relation of fever to meteorological conditions prevailing in the province of Rome within the terms of a mathematical formula which would have been utterly impossible unless these

conditions were necessary for the production of the disease—necessary for the production of the organism is the reply which may be made, but, as has been shown above, the organism of malaria must be gifted with capacity for adapting itself to widely different conditions, such as no other organism possesses.

Relation to cultivation.—That in the province of Rome the malaria has spread and increased *pari passu* with the destruction of the ancient cultivation, and of the woods and forests, is a matter of history; the increase of marsh land in the plain, as a consequence of the stripping of the timber from the mountains, and the evil results which have flowed from it, are likewise beyond dispute, and *per contra* there is a large amount of evidence to show that high cultivation, and especially the planting of trees, tends materially to diminish if not entirely to destroy malaria.

The amelioration of a malarious country by cultivation is of two kinds—general, from the effects produced on the climate by drainage and planting,—and local. The influence of trees and crops upon climate is now well recognized, and is not difficult to understand. Where the land is uncultivated and barren, the heat of the sun by day bakes the soil and evaporates the water from it, to fall again at night in the form of mist or heavy dew, owing to the excessive radiation which takes place. When the soil is covered by trees and crops, it is protected from the heat by day, the evaporation is consequently very much less and, for a similar reason, the radiation at night is enormously diminished, with the result that instead of violent extremes of heat and cold and an atmosphere always more or less saturated with moisture, an equable climate is produced. We know that coincidently the malaria is diminished—whether in consequence of the moderation of the climate or of the removal of excess of water from the soil and consequent destruction of conditions favourable to the growth of an organism, is the question at issue. That cultivation equalises the distribution of heat and moisture and so moderates climate is an accepted fact, and evidence has been adduced that these effects are produced over very small areas;

further, we have found that local climate and the local distribution of the disease are very intimately associated. It is not, however, by any means clear how this change of climate can affect an organism. The drainage and the admission of light and air to the soil undoubtedly will produce changes which might interfere with the growth of some of the lower forms of life, and the fact that the disease is most prevalent where these conditions are absent lends some support to the theory; but, as has already been pointed out, the organism must possess an extraordinary power of adaptation to circumstances if it can thrive equally well on a bare rock, or in a swamp, so that the mere equalisation of the day and night temperature, or the removal of the excess of water from the sub-soil can hardly be alleged to affect it. The idea that trees may act as a screen or filter, holding back a particulate poison borne by the wind, must be definitely abandoned; all the common facts regarding the disease are against the existence of any such wind-borne poison. Thus, from a consideration of the relation of malaria to cultivation we derive no arguments in support of an organism, but we establish a still closer relation to those climatic changes which have already been shown to be intimately associated with the disease.

Relation to population.—The relation of population to malaria is so definite that we may lay it down as a law that malaria increases in intensity from the centre to the periphery of any large town or city, and in general terms malaria is inversely proportional to density of population. If the cause of malaria be an organism, it is certain that it does not obey the same laws as those which are believed to be the cause of many other diseases, and which appear to flourish especially in densely populated neighbourhoods. Whatever else it may be, malaria is not a filth disease, but the reverse. The crowded slums of Rome are free from it, whilst the country houses of the wealthy are uninhabitable in summer; the micro-organism of malaria, if such there be, requires fresh air and the soil of the open country for its development. The effect of population in diminishing the disease is, on the hypothesis of causation

by climatic vicissitudes, precisely what we should expect. It has been demonstrated that the difference between town and country in respect of these variations of temperature and atmospheric moisture is very great, and we are perfectly justified in assuming that within a town these changes increase in intensity from the centre to the periphery. It is equally a fact that within the walls of the City of Rome at all events the disease has been steadily driven out by the advancing streets and buildings, until the malarious areas have been reduced to relatively insignificant limits. Possibly the conditions favouring the growth of an organism have been thus modified, but it is a fact that the area of more equable climate has been increased.

In this connection, the curiously perfect localisation of the disease requires consideration. It might be urged, and with a certain amount of reason, that it is impossible that there should be any sharp line of demarcation between the malarious and non-malarious portions of any given area; nor are the remarks on the subject in a preceding chapter (Chap. X.) intended to convey the impression that these boundaries can be very accurately defined. It may be said with truth that the contadini of the Roman Campagna frequently regard a few metres as of great importance; this, however, requires some explanation. The author has found in investigating these cases of supposed very sharp demarcation between very unhealthy and comparatively healthy spots, that there was invariably a difference in the character of the soil, the former being damp and the latter dry. From the account given of the soil of the Campagna it is not difficult to understand that this should be the case, and the extent to which it is true may be conveniently expressed by saying that it would be undoubtedly safer to sleep in the middle of a paved road than on the grass on either side of it, and no inhabitant of the Campagna would hesitate if the choice were open to him. That he would be absolutely safe is not true, but that the risk would be less is, in the author's opinion, hardly open to doubt, whilst if we extend the difference of position to a kilometre or more, comparative immunity may be secured in many

cases. Of all the phenomena connected with the disease, this is perhaps the most puzzling. If malaria be due to an organism, it seems incredible that it should not be capable of being carried by the wind or by currents of air over such small distances, and yet all the evidence we have is against a wind-borne poison, Again, there is no doubt whatever as to the value of very insignificant elevation above the soil as a protection. We must presume that the organism, if it exist, can rise in air to the height of a man's mouth or even higher, and yet at ten feet above the soil the protection is great, and at twenty feet not far from absolute. There is yet another strange fact, if the poison be particulate, namely, its apparent inability to climb a very insignificant hill. The case of the osteria and house at San Paolo seems impossible on the hypothesis of a particulate poison or organism. We may, it is true, regarding some amœbiform organism, such as the *plasmodium malariæ* is supposed by its discoverers to be, as the cause of the disease, explain these difficulties by saying that it cannot leave the soil at all, or at the most only reaches the level of the herbage growing on it; this explanation carries with it as a necessary corollary the assumption that the poison finds its way into the body only through food or water, which is utterly at variance with observed facts. If we conceive the poison to be, to all intents and purposes, an aquatic organism, this explanation will serve in some cases, but breaks down utterly if applied, as it must be, to all. Why should it be more or less safe to work in the fields all day, provided that the labourer be housed in the city between sunset and sunrise? This practice is attended with such well-nigh intolerable inconvenience that the contadini would certainly not adopt it unless some real and solid advantage were thereby obtained. The advocates of the organism theory are aware of these difficulties as to the carriage of the poison and its mode of entry into the human body, and Professor Crudeli has endeavoured to meet them by supposing it to be carried upwards by the currents caused by radiation from the surface of the soil at certain hours of the day; but why it should rise a certain distance at these hours and yet fail to be

transported horizontally to any extent, seems inexplicable. If it be a bacillus its spores must be capable of destruction with a facility not common to such organisms, and it is simply incredible that the trifling elevation known to be more or less efficacious should afford the slightest protection. Turning to the other hypothesis, we find a reasonable explanation of all these difficulties, or perhaps we should say that we have found by direct experiment a factor which is undoubtedly subject to variation under all these circumstances, and of which we can say that, if not itself the cause of the disease, it is so intimately bound up with it that no theory which ignores it can be allowed to be worthy of consideration.

We have thus far confined ourselves to what may be called the external phenomena of malaria, but the disease itself favours the hypothesis that climatic vicissitudes play an important part in its causation. We have spoken of variation of intensity of the disease with latitude, and we have found that this must be interpreted to a very large extent as variation of type, that is to say, as the latitude diminishes so does the period of rest between the attacks diminish until it tends to disappear altogether; so that in the place of the quartan ague of Sweden we have the remittent and continuous forms of the Tropics. If malaria be the result of the action of a pathogenic organism upon the human body, it must be the same organism in all cases of whatever type, for the first step towards recovery from the continuous form is its conversion into a remittent, and this again into quotidian, tertian, and quartan, though the whole of these stages are not necessarily passed through in all cases. The germ theory offers us no explanation whatever of this peculiarity of the disease. We now understand what is the meaning to be attached to the word intensity, when applied to malaria; a patient will survive many attacks of tertian or quartan ague, or even quotidian, in which the fever may be very high; but if the high temperature be continuous even though not very excessive, his life may be in peril. Such cases always demand prompt and energetic measures. It is very difficult to understand why an organism in the latitude

of Sweden should behave so differently when transported to the Equator or even so far south as Rome. We cannot compare a quartan ague with a remittent as we would one case of typhoid fever with another, for the differences are not merely of degree but undoubtedly due to a multiplication of accesses comparable as before said (Chap. XVIII.) to the combination of stimuli, by which the curve of tetanus is produced, and this can hardly be said of any other known disease.

Lastly, though in all diseases the well-clad and well-fed escape to a greater extent than those who are habitually underfed and insufficiently clothed, and though robust health is a great protection against all disease, there is no disorder of which it can be said that good food and sufficient clothing are prophylactic to the extent to which they undoubtedly are prophylactic against malaria. The traveller who is at all times well fed and clothed, and who, if compelled to camp in the open, has the means of avoiding all risk of chill, may as it were live in the midst of the conditions under which the disease may be acquired and yet escape; let him, however, be guilty of some slight indiscretion, over fatigue, neglect of food, or incautious exposure to damp and cold, and, strong though he be, he may find himself stricken with a disease which will cling to him for life.

CHAPTER XXV.

REMEDIES, THEIR NATURE AND MODE OF OPERATION.

THERE is perhaps hardly any disease in which the action of remedies is so prompt and so certain as in intermittent fever, and there is certainly no disease in which the treatment of an uncomplicated case is so simple and effective. The remedies are so few in number and so definite in their action that we are justified in arguing something from them as to the nature of the disease.

For this purpose it is unnecessary to consider the very grave and complicated types of malaria. It will be sufficient if we investigate the results of certain methods of treatment upon the types of well-marked periodicity.

Inasmuch as we are justified in regarding anything as a remedy which is capable of modifying or cutting short an attack of ague, we have first to consider the action of food.

It has already been shown that those persons who are well fed have much less to fear from ague than those whose food is scanty or insufficient, and that good food and warm clothing are among the best prophylactics against the disease. Examples have been given of the value of food as a remedy in the case of persons already attacked by malaria, and, in the author's opinion, a very large number of cases, especially those occurring in a poor and underfed population, may be successfully treated by the judicious use of a generous diet alone. It is a well-recognized fact that fatigue and exhaustion especially favour the development of malaria in the individual, and it is equally true that those persons in whom the processes

of repair are defective, and who cannot take a quantity of food sufficient to provide the energy required to meet the strain put upon them, very quickly break down and are then in a state in which they are especially liable to acquire disease of any kind. Such persons are constitutionally unfitted for the endurance of hardship, and should recognize the fact and conduct themselves accordingly if they would preserve their health in a malarious climate. The same result appears to be brought about in robust and healthy individuals by prolonged insufficiency of food combined with hardship, and the peasantry of most southern climates are in this condition. The popular idea is that they have a wonderful capacity for work upon an exceedingly limited amount of food, and it has been gravely argued from their example that we northern nations consume much more food, and especially meat, than is necessary. Careful comparison and observation is all that is required to demonstrate the utter fallacy of this reasoning. It has been pointed out before, and it is hardly necessary to repeat it again, that the Campagna labourer, though he toils from daybreak to sunset, does not accomplish a very large amount of work, nor should it be expected of him; *ex nihilo nihil fit* is a law which cannot be set aside even in the case of so nearly perfect a machine as is the human body; but when that body is supplied with barely more food than is required for its maintenance in a state of perfect rest, it is unreasonable to expect the development of a large amount of energy in the shape of external work. These people then by reason of the very conditions under which they live are especially prone to disease of any kind, and their capacity for resisting malaria is almost *nil*. It is therefore not altogether strange that, in their case, a generous diet should to a large extent take the place of medicine, and that a meal of meat with wine, or even without, should so raise their powers of resistance that an attack of intermittent fever may be prevented by it, almost as certainly as by the administration of quinine or some other specific remedy. There is a strange superstition in the Campagna which appears also to be common in all malarious countries, that to eat during an attack of ague is to aggravate the

disease; this has been extended to certain articles of diet, especially fish and eggs. The explanation is more or less simple: of all the causes which will provoke a return of the disease in a person who has already been infected, there is perhaps none so powerful as dyspepsia, and to eat *during* the fit would almost certainly aggravate the malady. Unfortunately this reasonable idea has been extended to the starving of a fever patient so long as the disease lasts, with the result that each attack finds him very much weaker and less able to bear it than before.

The author experienced the effect of this superstition when first attacked by the disease; the exhaustion produced by a double quotidian ague with a temperature of 105° F. was great, and in the interval between the attacks the desire for food was intense. The knowledge that another access, possibly more severe than the last, would begin in twelve hours, only served to emphasize the necessity of preparation for the waste of energy which was to come, by taking food; yet, it was only after the most urgent entreaty that food could be procured, and the fact that the patient did not die but rapidly improved was regarded as something very extraordinary, only to be explained on the ground that an Englishman was differently constituted from an Italian.

Alcohol in the form of good red wine is undoubtedly of service in some cases, especially those in which the accesses are slight and ill-defined, and it would appear that the tonic effect produced by both food and alcohol is frequently sufficient to diminish the severity of an attack and in some cases to cause it to fail altogether.

There are few diseases for which we can say that we possess a specific remedy, still fewer in which the action of the remedy is so certain as that of quinine in malarial fevers. It is not our business to discuss in detail the proper treatment of a case of ague, but there are certain facts connected with the administration of quinine which are of importance to our subject, and which will assist us materially in forming an opinion as to the nature of malaria. Quinine is regarded by the advocates of the "germ theory" of malaria in the light of

a poison to the specific organism, and, if the presence of certain organisms in the blood be the cause of the disease, it would seem reasonable to administer quinine at any time in order to destroy them, or prevent their development; such, however, is not the case. If a sufficient dose of quinine be given during the period of intermission, the ague will either not return at all, or be greatly diminished in severity, disappearing entirely after a second or third dose of the alkaloid; if on the other hand the drug be given during the fever, although the temperature of the patient may be lowered and the symptoms modified, the curative effect will be very small, and the subsequent attacks very irregular in their period. Generally speaking, it appears to be wiser not to interfere at all than to give quinine, particularly large doses, during an access of ague, as more harm than good will probably result.

Another peculiar property of quinine is its power to change the type of the disease and to lengthen the period of intermission; thus a double quotidian will become quotidian or tertian, and the new type will require the same treatment as the original. As a rule this is not allowed to develop itself, the administration of the quinine being persisted in until the patient has been entirely free from the disease for some days. When cured in this way the ague may not return again for years, perhaps never, but the patient as long as he lives will remain liable to attacks of intermittent fever. From this action of quinine and the fact that so far as we know it is incapable of effecting a radical cure, it is to be regarded as strictly antiperiodic in its action, not destroying the cause of the disease, but simply preventing the development of its effect.

We might represent the various types of the disease by the oscillations of a pendulum, the period of the oscillation representing the type, and the amplitude the intensity, of the fever; the action of quinine given before an attack would be represented by a lengthening of the pendulum; its effect during an attack by an obstacle so placed as to interfere with the amplitude of one oscillation, or by a momentary alteration

of the point of suspension. We shall in the next chapter amplify this illustration and apply it to the explanation of the phenomena of the disease.

There is one other remedy, which is of great and increasing importance in the treatment of ague, namely arsenic. It has been used for ages in the East, but it is only in recent years that any attempt has been made to ascertain its true therapeutic value in intermittent fever. The observations carried out in Italy at the suggestion of Professor Tommasi-Crudeli upon railway employés, soldiers, and others,* have led to the following conclusions, amongst others (*l. c.*, p. 16):—

"1. It appears to be established beyond doubt that the continued use of small, daily doses of arsenic increases the resistance of the human organism to the attacks of malaria."

"2. This increase of the specific resistance produces sometimes complete immunity in the individual treated with arsenic, more often a partial immunity. In the second case the organism under the influence of arsenic is less susceptible to the pernicious forms of the disease, so that, when attacked by the fever the disease is generally of a mild type, yielding readily to moderate doses of quinine."

"3. In order to obtain this effect, more or less completely, upon the human organism, *i.e.*, an absolute or relative incapacity for becoming a suitable cultivating medium for the malarial ferment, three conditions appear to be necessary:—

"*a.* That the daily dose of arsenic shall be gradually increased, in countries in which the malaria is severe, up to ten or twelve milligrammes, care being taken to divide the daily dose and never to administer it upon an empty stomach."

"*b.* That this administration of arsenic shall be begun some weeks before the supposed fever season."

"*c.* That in the case of individuals already greatly deteriorated, either by poverty or the effect of previous attacks

* "Sulla preservazione dell 'uomo nei paesi di malaria. Seconda relazione di Corrado Tommasi-Crudeli." *Annali di Agricoltura,* 1884, No. 81.

of the disease, the nutrition should be improved so as if possible to bring them up to an average standard, which may be increased by the use of arsenic."

"*d.* In order to effect this improvement in nutrition, Professor Crudeli suggests the use of desiccated blood which he believes to be especially useful in the anæmia of malaria."

Arsenic, though not so markedly antiperiodic as quinine, is undoubtedly of great value in the treatment of malarial fevers, and when given in comparatively large doses (ten drops of liquor arsenicalis (Fowler) three times a day) will produce an excellent effect in some cases of obstinate tertian and quartan ague, especially in cases of relapse, such as may be seen in large numbers in Rome in late autumn. The Italian experiments afford good ground for the belief that arsenic is, to a considerable extent, prophylactic against malaria: out of 452 persons experimented upon in the year 1883, 321 escaped the fever altogether, seventy-six were attacked, and in fifty-five cases the result was from various causes doubtful. There is some difficulty in persuading the people to take it, even when it is made up into gelatine plates of very small size and absolutely tasteless, arsenic being regarded only as a poison, and quinine as the sole remedy for the fever. This is, however, being gradually overcome, and in some of the most unhealthy districts "arsenic parades" are held daily, with the most encouraging results. In the author's own case the use of arsenic, when a return of the fever was threatened, has been almost invariably attended with good results, and a few doses of a combination of Fowler's solution with quinine (three grains of quinine and three drops of the solution taken three times a day after food) has sufficed on several occasions to break the habit of a slight but obstinate quartan ague, when much larger doses of quinine alone had produced only a temporary effect.

The treatment of ague by large doses of calomel or of opium, with emetics and diaphoretics, as practised fifty years ago, though violent, appears to have been more or less effective, at all events for a time; but these methods have long since given place to a more rational treatment. The

domestic remedies for ague are simply legion, most of them harmless, some very disgusting, and a few probably to some extent useful. There is an ague drink in use in Italy which seems to have a distinctly beneficial effect, and which probably owes any virtue it possesses to its diaphoretic action and the bitter principles it contains. It is prepared as follows: take a fresh lemon, cut it into thin slices, rejecting nothing, and set it on the fire in a perfectly clean earthen pot in a pint and a half of water; allow it to simmer until the fluid is reduced to half a pint, then strain the decoction through a linen cloth, squeezing strongly in order to express all the liquid; allow the decoction to stand for several hours and cool; the popular plan is to set it out of doors all night. The liquid so obtained is bitter, but not altogether disgusting. It is usually given some time before a meal, or before the expected attack, and appears not to be without some febrifuge properties. A similar drink is made in Guadaloupe, from the outer portions of the root of the lemon-tree (*Annali di Agricoltura*, No. 81, p. 14).

It is somewhat remarkable that of the two remedies of undoubted value in the treatment of intermittent fever, both are tonics; one is the most powerful antiperiodic known, and the other, though generally reckoned as such, is relatively feeble in its action. In addition to these properties, arsenic appears to have some specific, though little understood, action upon nutrition. Professor Crudeli speaks of arsenic as increasing the "specific resistance" of the body to malaria; defective digestion and assimilation are well-recognised results chronic malaria, and it is in these cases that arsenic is especially valuable, so that we should possibly understand by increase of the specific resistance, increased activity of the functions of nutrition. Bad and insufficient food undoubtedly predisposes to malaria, and that a drug which is known to assist assimilation should increase the power of resistance to the disease is only what might be expected.

These two remedies therefore act:—1. As nervine tonics. 2. As promoters of assimilation and nutrition. 3. On the germ theory of the disease, as poisons to a specific organism.

The difficulties in the way of the acceptance of the last-named mode of action have been already referred to, and, if we reject the hypothesis of a pathogenic organism as the cause of malaria, we shall be practically bound to regard the disease as a disorder of the nervous system, or of the functions of nutrition, or both.

CHAPTER XXVI.

MAY MALARIA BE REGARDED AS A PURELY NERVOUS DISORDER?

OUR criticism of existing theories as to the nature and cause of malaria has thus far been more or less destructive. The "germ theory" is difficult to reconcile with the facts and the "chill theory" in the crude form in which it has been stated by its originators can only be regarded as a suggestion. We have practically come to the conclusion that it is between the "germ theory" and what we may call the "nervous theory" that we have to make our choice; no other road seems open, and, if we reject the pathogenic organism, we have only physical causes operating upon the human nervous system, or rather a certain part of the nervous system, to fall back upon. It is not difficult to perceive that by adopting this course we are to some extent compelled to elaborate a physiological theory of fever, and that such a theory as shall embrace and explain all the facts relating to malaria of which we are cognisant. The facts which we have to coordinate, and on which any theory proposed must be based, have been already set out at length and they do not require to be repeated. We may however allow ourselves to consider for a moment—What is malaria? *i.e.* In what respect does malaria differ from other febrile disorders? It has been shown that it is possible for an individual in perfect health, after exposure to conditions prevailing in certain localities, to acquire a disease, the chief characteristic of which is a simple fever, differing only from other forms of fever in that it will return with the utmost punctuality at fixed and well-defined intervals. The

fever may be exceedingly slight, as measured by the thermometer, or it may be severe, and the anatomical lesions may be so insignificant as not to be traceable in any of the organs or tissues of the body, The whole of the symptoms may disappear without specific treatment and leave the subject of them apparently perfectly well; he may remove immediately from the locality in which he acquired the disease to one in which it is entirely unknown, and many years afterwards all the symptoms of periodic fever may manifest themselves in his body, as the result, or as concomitants, of some entirely different disorder, either disappearing with this disorder or resuming their original activity sufficiently to require special treatment. These are the important facts of malaria, and any theory we may devise must account for fever, periodicity, and continued liability of the individual.

The fever is not peculiar to malaria, or perhaps we should rather say that there is nothing in the symptoms of an attack of malarial fever which serves to distinguish it from other simple fevers unless it be the marked division into phases. The continued liability may perhaps be regarded as presenting nothing which is unknown in other diseases, and we are consequently left with periodicity as the characteristic of malaria. A careful study of the variations of temperature in other febrile disorders reveals the fact that very well marked periodicity is by no means uncommon and is almost characteristic of some diseases; it is thus hard to resist the conclusion that in malaria we have to deal, if we may so say, with the normal physiological process of fever and that, in the simplest form, intermittent fever is rather a question in pure physiology than in pathology as ordinarily understood, if indeed it be possible to define the boundary between the two sciences. Every increase in our so-called pathological knowledge tends to destroy this distinction and in dealing with malaria it seems to disappear entirely. The gist of the whole argument is this :—Many of the normal functions of the body are periodic, some manifestly so, whilst in others the fundamental rhythm or periodicity only reveals itself as the result of physiological experiment, which in the majority of cases takes the form

of removal, or obstruction of the control of the central nervous system. Hence it is at least possible that periodic fever may result from damage to the thermotaxic nervous system and we have to consider how far the various phenomena of ague are consistent with interference with a rhythmically acting nervous mechanism controlling the production and dissipation of heat in our bodies and further, how far we can account for these phenomena as the result of the operation upon the human organism of the conditions known to exist in malarious countries.

The phenomena to be explained belong unfortunately to a branch of physiology which is as yet in its infancy, and concerning which our positive knowledge is exceedingly small. The production and dissipation of heat by the animal body involve such complicated considerations that at the best we can but formulate a reasonable hypothesis as to the mode of causation of a disease which we find ourselves compelled to regard as the result of some interference with these functions.

The production of heat is mainly if not entirely due to the oxidation of the tissues, and this is dependent upon the supply of food and on the energy of the oxidation processes ; under ordinary circumstances in health, the processes of waste and repair balance one another and the practically constant temperature of the body is a proof of the perfection of this balance.

The temperature curve in health exhibits a periodicity which is independent of food and in fever this diurnal variation becomes excessive ; so much so, that the temperature curves of some diseases bear a very close resemblance to those of quotidian ague and, as Dr. Burdon Sanderson says, "the only material difference between the two conditions (healthy and febrile) is, that in fever the normal is 3·26 F. higher. Whatever be the explanation of this, the fact comes out so clearly as the result of observation that it cannot be disputed." The temperature of our body represents the resultant of two opposing forces, the production and the dissipation of heat, and we can readily understand that fever might be produced either by excessive production or diminished dissipation, or

both, and whilst increased production is the most important cause of the rise of temperature in fever, diminished dissipation plays its part, at all events in ague.*

That the body temperature is chiefly controlled by the vasomotor system admits of no doubt, but there is a large amount of evidence to show that the production and dissipation of heat is not entirely dependent upon blood supply, and that the nervous system exercises a more or less direct control over the oxidation processes of the body.

Of the exact nature of this control we are ignorant, but that it is intimately connected with the processes of nutrition is certain. The food we eat is not immediately converted into force in the body; the ordinary wear and tear is probably repaired in health almost as rapidly as it occurs, but when occasion requires, the oxidation processes become more active, the reserve of material is drawn upon, and the temperature of the body may rise considerably above the normal without in any way indicating damage to the organism. The balance is however only temporarily lost and so soon as the strain is removed will be restored. There are two facts regarding this disturbance which are important: the one is that the better the state of "training" of the individual the less likely is this disturbance of the balance of temperature, this waste of energy, to occur; the other, that, in those cases in which the work done is much beyond the real power of the persons doing it, the febrile state will often persist for several hours after the termination of the labour. Thus even in health we have evidence of the existence of a control over the production and dissipation of heat which is not always able to meet the strain put upon it, and the breaking of which induces a state of fever.

Fever may then arise in the human body merely as the result of the inharmonious working of the machinery which regulates the balance of heat production and dissipation; there

* In the cold stage of an ague the heat production may be as much as two and a half times the normal, whilst the rate of dissipation is diminished. In the hot stage the rate of dissipation increases but more heat is produced. In the sweating stage the dissipation is greatest and may be two or three times greater than the normal, the production being either increased, normal or sub-normal.

are no anatomical lesions, and the condition is in no way dependent upon any poison, or organism entering the body from without.

It is not difficult to understand why an attack of fever should result from excessive muscular exertion, but such fever is not periodic and will not return except on a repetition of the exercise and, as has been said above, if carefully led up to by a course of judicious "training," the disturbance will probably not occur at all. It would thus seem that the nervous system can be as it were taught to meet the strain put upon it, and it is a remarkable fact that by practice the amount of labour required in order to induce this febrile condition continually increases with each repetition of the experiment, provided the intervals are not too long, until it may be double or even quadruple that required on the first attempt.

The general influence of our surroundings upon the production of heat in our bodies and upon its dissipation is a well-established fact, so well recognized that our daily habits are to a large extent governed by it; and it is perhaps for this very reason that so little attention has been paid to the possible effect upon our bodies of variations of temperature and atmospheric moisture which are constantly occurring. In temperate climates we clothe and feed ourselves more in relation to season of the year than to actual climatic changes and, under ordinary circumstances, we are but rarely subjected to such vicissitudes as would lead us constantly to carry an extra wrap, as has been said to be the common practice of the inhabitants of the Roman Campagna. Nothing can show more clearly the difference between the climate of this part of Italy and that of England for example. In England the changes are rarely so great but that we can tolerate, for a time at all events, the inconvenience of a little too much or a little too little clothing; but in the Roman Campagna it is otherwise—there, in summer, clothing which would be intolerable by day by reason of the heat is utterly insufficient to protect the body from the relatively intense cold at night.

It is not enough for our purpose simply to record these facts, we must go further and inquire, so far as our very limited knowledge will allow, what happens in the human body when fully exposed to these changes.

Attention has already been called to the fact that for almost every individual there is a temperature of the atmosphere which he will regard as hot and another which he will regard as cold. The limits will vary considerably in different persons, but in England at all events most people will begin to complain of the heat when the thermometer reaches 70° F., that is to say, a temperature almost thirty degrees below that of our bodies. The physiological significance of this sense of heat is very plain, it is an indication that the heat-regulating apparatus of the individual in question has begun to feel the strain put upon it in order to maintain the body at its proper temperature.

It is fair to suppose that, as the temperature rises, the strain becomes greater; and there is perhaps nothing more remarkable than the differences which exist between individuals in their capacity for tolerating heat. Some are prostrated by a temperature but little above that at which they first experience a sense of heat, others can work and enjoy life even under a tropical sun.

Side by side with these facts we must place another, equally well ascertained, namely, that our bodies become accustomed to a gradual rise of temperature or to a gradual fall such as occurs in spring and autumn, with the result that though the actual temperature may be the same, we may properly describe a day in July as being cold which would have been regarded as very hot in April: for example, if the temperature in July has been at or about 70° F. for some time and were suddenly to fall to 65° F., we should say that it was cold; whereas in April a rise of from 60° F. to 65° F. would cause complaint as to the heat, although the actual temperature which produces these different sensations is the same. In neither case, however, is the difference of temperature sufficient to cause us materially to alter our habits of life, and it is not until these changes have been repeated many times that we abandon our

winter clothing in the one case and assume it in the other. It occasionally happens, even in England, that in summer the weather "breaks" and the thermometer falls sufficiently to compel us to light our fires and take other means for keeping ourselves warm. This, which occurs in England to a very limited extent and so gradually as to be easily met and tolerated, takes place nightly in summer and autumn in the Roman Campagna, and instead of a fall of 5° F. or 10° F., the difference may, within twelve hours, be as much as 40° or even more. In England sudden changes of temperature may, and frequently do, produce bad effects, and the possible results of what is popularly known as "a chill" are too well known to need description; but between such a chill during summer in England and that which may be experienced on any summer or autumn night in the Roman Campagna there is a wide and important difference. Not only is the range of the fall very much less in England, but it occurs in a very different part of the temperature scale. It is, in fact, a fall from a temperature by no means hot to a temperature by no means cold, the organism is under little or no strain in combating the higher temperature, and under ordinary circumstances the lower one is easily tolerated; in a word, the difference is relatively insignificant. The daily range of temperature in the open country round Rome during summer and autumn is not only enormously greater, but begins from a point far above that which most persons can be said to endure without strain. Judged by simple experience—for there is but little experimental evidence to go upon—the strain produced by a rise of temperature from 80° F. to 90° F. is far greater than that caused by a rise from 70° F., to 80° F., and it is well known that like changes at the other end of the scale do not produce corresponding sensations; that is to say, when the temperature is already some degrees below freezing we do not experience anything like the discomfort from a further fall of several degrees that we should from an equal fall of temperature in summer. We are thus made aware that, great as our power of accommodation to changes of temperature is, it has limits, and that these limits are more quickly

reached for heat than for cold; further, that whilst our bodies can readily adapt themselves to even considerable changes, provided only they be gradual, the power of adaptation fails when the changes occur very rapidly.

A little consideration will show that this is perfectly reasonable; it is undoubtedly easier to increase our production and diminish the dissipation of heat from our bodies in order to resist cold, than it is to diminish the production and increase the dissipation in order to resist heat.

The very fact that we possess this heat-regulating mechanism adds to our difficulty in resisting high temperatures, for, as has been shown, it is called into play long before the temperature of the external air approaches that of our bodies, so that a person exposed to a climate the mean temperature of which is very high is engaged during the whole time of his residence in defending himself against it. That this defence involves the continual consumption of energy in one form or another is hardly open to question.

We are further led to the conclusion that our thermotaxic apparatus is not so mobile as is generally supposed, but that it is as it were set, or sets itself, to control the circumstances under which it is *generally* placed, and that if these circumstances be suddenly and violently altered, it requires so much time to accommodate itself to the new conditions as to become practically inefficient.

It is conceivable that under such conditions as prevail in the Roman Campagna, unless the greatest possible care be taken to protect the organism from these violent changes, the thermotaxic mechanism may be unable to follow them with sufficient rapidity, and thus set up in the body conditions exactly the reverse of those which under the circumstances are most necessary for the comfort of the individual.

The deductions to be drawn from our habits and sensations, as effected by the temperature of the atmosphere,* may be summarized as follows:—

For every individual there is a temperature at which he is

* Apart from the effect of atmospheric moisture, which will be considered separately.

more or less unconscious of either heat or cold, and this, though varying with the individual, is in all cases many degrees *below* the normal temperature of the body.

The variations of temperature, above or below this point, which may occur without causing some discomfort are very limited, the *rate of change* being the most important factor in determining the intensity of the sensation produced.

Our heat-regulating apparatus may thus be regarded as set for a certain range of temperature: if the changes be gradual it can within this range accommodate itself to the new circumstances, but if on the other hand the changes occur outside this limit and are at the same time very rapid and excessive, the failure of the organism to adapt itself to the new conditions is much more marked, and it is conceivable that it may break down altogether. Our sensations of heat and cold are to a large extent the result of processes going on in the body, and when we say that a certain temperature is unbearable, it amounts to a confession of failure on the part of our heat-regulating apparatus.

It may be asked—Is there any proof, other than that afforded by our sensations, that the heat-regulating mechanism is set for any particular range of temperature, and that the organism is subjected to strain when these limits are passed in either direction?

It is a well-known fact that in healthy, active persons, cold increases the appetite, that is to say, the low temperature creates the necessity for increased oxidation in the body, the material for which is supplied by food. It is generally supposed that great heat has the reverse effect, and that as heat is supplied from without there is less necessity for supplying it from within. In the author's opinion, so far as limited observation upon himself and others during the heat of summer in the Campagna affords a criterion, such is not the case, but rather the reverse. It may be necessary to modify one's diet in a hot climate, but good and suitable food and this in abundance appears to him to be just as necessary in order to successfully resist heat as to resist cold. The too common practice of allowing the appetite to give way when the

external temperature is high is in his opinion not only harmful but scientifically wrong, and, although it may at first sight seem paradoxical to supply material which will produce heat to a body already suffering under a high external temperature, on the hypothesis that this high temperature causes a great strain upon the organism and that such strain whatever its exact nature may be probably means excessive tissue change, it is after all as reasonable to compensate this waste by food, whether there be appetite or no, as it is to satisfy the cravings of hunger caused by similar waste under the influence of extreme cold. Nor are we altogether without some experimental evidence of the existence of what we may call a critical point in the metabolism of the organism. Page* has shown that in a dog "there is a temperature of the surrounding medium at which the carbonic acid discharge from the animal is at a minimum: below this temperature the quantity of carbonic acid discharged increases as the temperature falls, above this the discharge also increases and at high temperatures 40°—42° C. the increase may be very rapid."

So far as the production of carbonic acid is an indication of the activity of the oxidation processes of the body, there is evidence therefore that a high external temperature causes increased metabolism and justifies our belief in the strain caused to the organism by sudden and violent changes of temperature occurring at or about this critical point. If the metabolic phenomena be directly connected with the efforts of the organism to accommodate itself to the changes in surrounding conditions, it is not difficult to understand why the effort should sometimes fail, and why the organism should be unable to respond to the calls made upon it. Our sensations of heat and cold are, as has been said, presumably to a very large extent the expression of some process or processes going on within the body. If these processes be fundamentally metabolic, it almost follows that they cannot be set in motion, or, if set in motion, that they cannot be stopped with the same promptitude as some more purely nervous process.

* *Journal of Physiology*, vol. i. pp. 228–34.

We may very aptly compare the working of these metabolic phenomena to that of a marine engine, we do not expect such an engine when going "full speed ahead" to respond at once to the order "full speed astern," and this is precisely what the heat-regulating machinery of the body is called upon to do at least twice in the twenty-four hours in the Roman Campagna.

Throughout the heat of the day the struggle to keep down the temperature of the body is more or less acute, and, if the experimental results just quoted are to be applied to man, during this period there is a greatly increased metabolism, which will continue during almost the whole time that the sun is above the horizon. The moment the sun goes down the temperature begins to fall with such rapidity that, to use our metaphor, the engines have soon to be driven "full speed astern," to be again even more suddenly reversed at sunrise. Dividing the twenty-four hours into daylight and darkness, we may say that this increased metabolism, caused by high external temperature, is carried on for about sixteen hours, during the greater part of which at least it can only be regarded as abnormal. The period of rest cannot be said to endure for more than two or three hours to be again changed for a period of five or six hours of increased metabolism in order to bring about the opposite result, and again at sunrise there is another change if not in the nature at least in the object of the metabolic phenomena, and even more sudden than that which occurred at sunset on the preceding day.

If we assume that the reaction period of these metabolic processes has any reasonable duration, it would seem to be at least possible that in some cases the machinery might refuse to respond with sufficient rapidity to the demands made upon it, should in fact become inefficient and, as a result, the production and dissipation of heat by the organism would cease to be in harmony with the requirements of its surroundings.

We have thus far left out of consideration the efforts of the individual to meet these violent changes, and the action of the aqueous vapour present in the air in increasing their effect.

It is well known that a dry heat is much more tolerable than a damp heat, and that even intense cold, provided the air be dry, is exhilarating rather than depressing; whilst a combination of cold and damp is perhaps of all climatic conditions the most difficult to meet.

In the Roman Campagna, during summer and autumn, the air is heavily laden with moisture, and at night almost constantly saturated. The effect of this excessive moisture is to impede the natural process of evaporation from the skin by day, while at night the abstraction of heat from the body is enormously intensified by the cold vapour in which it is immersed. It is only fair to assume that the work thrown upon the organism in order to maintain the body temperature at night is at least greatly increased by this envelope of cold aqueous vapour; and if we consider for a moment the intense discomfort which is caused during cold weather in England by an increase in the amount of moisture present in the atmosphere, it will be possible to form some idea of the sense of cold and misery which may be experienced on a summer night in the Campagna. In England a change of five or six degrees will cause a general outcry against the weather, but in the Campagna a fall of temperature from 100° F. or more to barely 40° F. occurs almost daily in summer and autumn, and the lowest temperature is accompanied by complete saturation of the atmosphere with aqueous vapour. It is unreasonable to suppose that this enormous daily range of temperature, with its accompanying heavy dews and morning mists, should be without serious effect upon the organism.

Assuming that malaria is due to these climatic changes, how can we connect them directly with the phenomena of the disease?

The normal temperature of our bodies is the result of the interaction of two separate factors, the production and the dissipation of heat, both of which, so far as our present knowledge goes, are under the control of the nervous system. The

relation of these two factors in health is such as to produce a daily rhythm in the temperature curve which is at least independent of food. There is, in fact, a normal periodicity in the human temperature which, if exaggerated, would practically represent a simple quotidian ague.

Rhythm as the resultant of two forces is best explained by rhythm in the components, and it is not difficult to imagine that the heat regulating mechanism consists of two rhythmically acting forces of such period that during one part of the twenty-four hours they are opposed to one another, and in another part acting in the same direction.

Whatever the mutual interdependence of these two forces may be, they are capable, when occasion requires, of acting independently of one another to a considerable extent, in response to stimuli from without. It is probable that, when the body is exposed to an increased external temperature, the apparatus for the dissipation of heat is called into play more quickly than that which controls production, and that when a sudden change in the other direction occurs, it is again the heat dissipating mechanism which responds most readily to the call.

So long as these demands upon the heat regulating apparatus are not outside the limits within which it is accustomed to act, they are tolerated by the individual, and no ill results are experienced beyond passing discomfort; but if these limits are constantly overstepped, and that to an exaggerated extent, the effects produced upon the organism may be such as to be beyond the power of the thermotaxic apparatus to control. The *effort* is made, nevertheless, and we have a right to argue that a certain degree of exhaustion results which can only be regarded in the light of damage requiring repair. What is the precise nature of the process of repair in this case we do not know, but arguing by analogy it is certain that *time* is required for its completion; further, if before it be complete a fresh call is made upon the apparatus it is equally certain that the failure will be greater than before.

If we admit the existence of any apparatus by which the

temperature of the body is controlled we must equally admit the possibility of its suffering fatigue, and as a consequence becoming more or less incompetent for the due performance of its functions.

There is hardly room for doubt but that it is the heat-dissipating apparatus which is most liable to break down under strain, and further, that the production of heat within our bodies is much more under control than its dissipation from them, whilst, as we have seen, there is some experimental evidence in favour of the increased activity of the oxidation processes of the body under the influence of an increased external temperature, so that the strain upon the heat-dissipating apparatus is probably in no small degree increased from within.

Regarding the temperature of the human body as the result of the interaction of two more or less rhythmically acting forces, the following hypothesis as to the causation of periodic fever is in the author's opinion worthy of consideration.

The exposure of the organism to sudden and violent changes of temperature and atmospheric moisture, by causing excessive strain upon the thermotaxic apparatus, destroys, either temporarily or permanently, the "harmony" existing between the components of this apparatus, thereby altering the form and period of the resultant curve.

It is difficult to express in general terms such an hypothesis as this, involving, as it does, the consideration of phenomena concerning which our knowledge is all too scanty, but the almost perfect rhythm of the temperature curves of typical cases of ague suggests irresistibly a comparison with the phenomena of interference and difference of phase in sound waves.

It has been shown to be at least extremely probable that the continuous, remittent, and other types of malarial fever are all modifications of one and the same disease, differing from one another only in degree, and the inference that they are the result of a disturbance of rhythmically acting forces is well nigh irresistible.

Granted this hypothesis and all the various forms of the disease, its strange proneness to change of type, the continued liability of the individual and the conditions under which it may reappear after long intervals of rest, become more or less comprehensible, and instead of a series of disconnected facts they become necessary parts of a continuous story.

Some of the simpler forms of intermittent fever may possibly be the result of difference of "phase" in one or other or both of the assumed components of the temperature curve, whilst those of higher frequency may better be compared to the "beats" produced by difference of "period."

Without insisting too much on the precise accuracy of the comparison, we might suppose the thermotaxic mechanism to resemble two strings of a violin, the fingers of the player representing the influence of external changes. By properly stopping both strings unison may be obtained at any desired pitch, or beats may be produced at will. The strings remain the same, it is only their mode and rate of vibration which is altered. Dissonance at a high pitch with a great number of beats might be taken to represent the practically continuous forms of the disease. Lowering of the pitch and also of the difference between the rates of vibration would in some degree represent the remittent types; whilst the more nearly the vibration numbers of the two strings approach one another the less will be the number of beats and the longer the interval between the accesses of fever. Thus, passing from difference of rate of vibration through difference of phase to unison, we may in a way represent every imaginable type of the disease. How far the behaviour of the thermotaxic nervous system under the influence of strain can be accurately illustrated by comparison with the results of the interaction of sound waves is perhaps open to question. The problem is very possibly much more complicated than we have supposed, nevertheless the comparison will serve better than any other to explain what, in the author's opinion, is at least a reasonable hypothesis as to the nature and mode of causation of malarial fevers.

We have still to deal with the continued liability of the individual. On the hypothesis advanced we may explain this

as the result of violent disturbance of the central apparatus by the original shock, or series of shocks, and the consequent direction of the nervous energy along unaccustomed paths, which, once opened, are liable to be used again if there be the slightest blocking of the original track. Perhaps it would be more correct to assume it to be the result of such a lowering of the "tone" of this part of the nervous system, that the new path becomes as easy as the old. On this hypothesis the action of such drugs as quinine and arsenic becomes comprehensible; they are tonics in the simplest sense of the word, and by blocking the bye-paths bring back the scattered forces to the main road.

The illustrations used above are exceedingly imperfect, and are only intended to assist in conveying to the reader the general lines on which, in the author's opinion, any theory which shall account for *all* the phenomena of periodic fevers must be built. The germ theory is, it must be confessed, utterly unsatisfactory. It will not explain either the periodicity of the disease or the continued liability of the individual; least of all will it satisfy the conditions under which the disease may be acquired or avoided.

We have still to account for these fevers, often of grave type, which prevail in localities almost waterless, often bare rocks affording no support to animal or vegetable life of any kind. Examples of malarious sites of this character are only to be found under the tropics and in places where the intense heat of the sun by day is followed by an equally intense radiation by night, unobstructed by a stratum of aqueous vapour on the surface of the soil, which, wet and chilling though it be in itself, does nevertheless materially assist in preventing an extreme lowering of the temperature. The effect on the human organism remains much the same; the actually lower temperature causes as great or may be even a greater strain than the dense layer of cold aqueous vapour.

Lastly, there are malarious climates in which the changes of temperature are by no means excessive. In all these cases the mean temperature will be found to be very high, and the

strain on the thermotaxic apparatus is practically all in one direction; the heat-dissipating mechanism is incessantly at work, struggling to save the organism from this strain, which we have with good reason assumed to begin the moment the temperature of the external air passes that point at which we begin to be conscious of heat. The individual capacity for resistance, the means taken to avoid this excessive strain or in other words the regard shown by the individual for the preservation of his health are factors which operate powerfully in determining the result in any particular case, but on the hypothesis advanced it is not difficult to understand why some should be attacked and others escape. In this connection also we may consider and to some extent understand those peculiar attacks of ague which apparently only manifest themselves *after* the subject of them has ceased to reside in a malarious climate. The acute disease which makes itself felt on return to a temperate climate is only an expression of the fact that the individual's thermotaxic apparatus was sufficiently elastic to be able to adjust itself to a great extent to new conditions, but that under the constant strain to which it was subjected it has lost its mobility and rebels against a return to the old order of things. Our hypothesis will also explain why in some cases after one or two sharp attacks the patient recovers more or less completely, whilst in others the disease lingers sometimes so obstinately as to defy treatment and ultimately cause the death of the patient.

The author is well aware that the theory advanced is little more than a theory, that the evidence in its favour is not of that definite and positive character which is required in these days from investigators. It is in his opinion however preferable to the alternative of a pathogenic organism whose *modus operandi* is utterly unknown, whose very nature is far from being determined, and whose direct connection with the disease is shadowy in the extreme. If there is any disease or group of diseases to which man is heir, and which may have their origin in what we call natural causes, without the inter-

vention of some specific microbe, surely the group of so-called malarial diseases may claim this distinction! To attribute to a whole group of diseases a purely physical origin, to regard them as the mere expression of the degree and manner of failure of the organism to accommodate itself to surrounding circumstances is a conclusion which will not perhaps commend itself to all, but in the author's opinion it is more reasonable to suppose that our complicated organisation may break down under strain, than to assume the interference of a pathogenic organism to be necessary for the production of periodic fever.

CHAPTER XXVII.

PREVENTION IN THE INDIVIDUAL AND CURE OF THE COUNTRY.

WHATEVER may be the cause of intermittent fevers, our practical experience of them is so vast and so ancient that we may claim to possess very considerable knowledge of means whereby the risk to the individual, under given conditions, may be reduced to a minimum ; whilst as regards the country, given time or money or both, the course to be pursued in order to render an infected area healthy and habitable is more or less clear—indeed it is, in many cases, only the magnitude of the undertaking which prevents its being carried out.

We have endeavoured to reduce to general terms the conditions favourable to the production of malaria, and have found that, so far as the eradication of the disease from the soil is concerned, the problem is one the solution of which lies with the engineer and the husbandman. All that we know of the aetiology and pathology of the disease adds little or nothing to our means of warding off its attacks ; though, as we have endeavoured to show, a critical examination of the methods taught by practical experience in almost every country of the world tends to demonstrate the real value of many of the expedients in use and the grain of truth which underlies much of what at first sight we might be inclined to regard as mere idle superstition.

Man is after all a very practical animal and we cannot afford to ignore the deductions to be drawn from his actions,

and this is especially the case when these actions clearly increase toil and diminish comfort.

The dread of wild animals will cause men to build their dwellings in trees or on high platforms, and the fear of their fellow-men will drive a large population from a fertile plain to barren and inhospitable hills. Where no wild beasts are found and there is no cause to fear the attacks of their own kind, and a population nevertheless adopts these practices, we argue, and rightly, that some other and overpowering advantage is gained which compensates the toil and hardship involved.

It is to careful observation of the practice of the inhabitants of malarious countries, and to this alone, that we owe our knowledge, such as it is, of the local distribution of malaria, and the best means at the disposal of the modern traveller are after all only those which have been known for centuries, carried out in the light of modern knowledge; the methods may be different, but the principles involved are the same.

An individual exposed to a malarious climate can do no more than avoid fatigue, take abundance of good food, keep his bodily functions in a state of proper activity, and above all avoid chill.

This is the best general advice which can be given at the present day, Hippocrates would have given the same centuries ago. The maintenance of the activity of the bodily functions and especially those of circulation and nutrition, appears to be of paramount importance and may be said to include, as indeed it does, all the rest. The avoidance of fatigue is a prophylactic against most diseases, as the power of resistance is undoubtedly greatly diminished by physical exhaustion. Again a generous diet is an almost universal safeguard, a properly fed individual being certainly less prone to disease than one whose nourishment is insufficient or of bad quality. Bodily activity within reasonable limits is a most important factor in the preservation of the general health, and to no one is it of greater consequence than to a person exposed to a malarious climate.

The specific resistance of the body to malaria, and indeed

any other disease, is greatly increased by a proper amount of exercise, and this is probably due to an increased elasticity, if we may so term it, of the functions, an increased capacity for responding to and recovering from an unusual strain, a quality especially necessary for the successful resistance of the effect of chill. The last precaution is the avoidance of chill itself. All our inquiries seem to lead us to sudden and violent changes of temperature as involving the cause, if they be not in themselves the cause, of malarial fevers, and the protection of his body against their influence is the first duty of the traveller in a country in which such fevers prevail.*

Side by side with these precautions is another of almost equal importance, namely, the protection of the body against excessive heat; we may express both in the advice to save the thermotaxic apparatus from *all* excessive strain.

Prevention, so far as the individual is concerned, resolves itself almost entirely into the strict observance of certain rules of life, regular and temperate habits, careful regard to food and clothing, and the avoidance of excess of every kind, for of no disease can it be so truly said as of malaria that good physical health is the best prophylactic. Drugs appear to be of but little use in this direction, though an exception should perhaps be made under certain circumstances in favour of arsenious acid, especially when the conditions of life are such that many of the general precautions cannot be carried out.

A resident population intimately acquainted with localities, and more or less instructed by long and painful experience in the best means of securing, under the circumstances, a maximum of health, is, in many respects, in a better position to avoid the disease than strangers to the country.

The soldier and explorer are especially badly placed in

* In Mr. Stanley's book, *Darkest Africa*, vol. ii. p. 31, he says:—"Emin Pasha informed me that he always took a mosquito curtain with him, as he believed that it was an excellent protector against the miasmatic exhalations of the night." Assuming Emin Pasha's faith in the value of a mosquito net as a protection against malaria to be founded upon experience—a possible explanation is forthcoming which is perhaps not at first obvious. To assume that the net filtered out a particulate poison is of course ridiculous, but on the chill hypothesis the function of the net is plain; it serves the same purpose as the fishing net used by gardeners to protect tender plants from frost by hindering radiation. W. N.

this respect; the conditions under which their work has to be done are, in the majority of cases, beyond their own control, and but too often are eminently calculated to increase their liability to the disease.

The precautions taken by the inhabitants of the Campagna to protect themselves against malaria have been described at length, and, so far as their limited means will allow, they obtain a certain measure of success. Bad though their circumstances may be, those of the soldier and explorer are often in many respects worse; true, he may not have to endure constant semi-starvation, nor is his life one of incessant and monotonous toil, but he may be, and often is, called upon to endure hardship and fatigue, such as the Campagna labourer could not endure. In addition, he must be constantly on the alert against other dangers, always ready for such service as may be required of him, service often laborious enough in his own country and climate, tenfold more laborious and exhausting in the tropics, where the ever-present malaria is a foe far more formidable than any other he is likely to be required to encounter.

To consider all that might be or ought to be done for the soldier engaged in what have been very aptly called "doctors' wars," or to lay down rules for the guidance of travellers in malarious climates, would be an impossibility; as, in either case, circumstances are sure to arise under which all such rules must be set aside and everything subordinated to some immediate and pressing necessity. This being the case, and bearing in mind what has been said upon the subject in the previous pages, it behoves all military commanders, leaders of exploring expeditions, and especially individuals, to do their utmost to keep themselves and their subordinates in as perfect a state of general bodily health as possible. This can only be done by the most careful regard to food and clothing that circumstances will permit, by the avoidance of all unnecessary exposure and fatigue, and the treatment of the slightest symptoms as soon as they occur by appropriate remedies.

The cure of a malarious country is a far more difficult and

complicated task, and even less certain than the protection or cure of an individual. Enough has already been said to show that before it can be attempted, a minute and accurate knowledge of local conditions, and of the distribution of the disease, is absolutely necessary. This can only be acquired in an inhabited or partially inhabited area; the pioneer in an unknown land must protect himself as best he may, and leave others to profit by his experience.

For our present purpose, the Roman Campagna will serve as an example of an almost uninhabitable area in the midst of an otherwise healthy and prosperous country; so much useful land at present untilled and untillable, owing to the prevalence of an endemic disease, which makes the risk of cultivating the soil greater than the gain. In the case under consideration, the local history of the country for centuries past is accessible; the time and circumstances under which the disease made its appearance at different points is, more or less, accurately known; a detailed survey exists; in fact, all the information necessary on which to base a plan of operations for ridding the country of the scourge, together with a vast amount of practical experience on the subject, not acquired yesterday, but the accumulated knowledge of centuries. Still the problem remains unsolved. Complicated political considerations have, no doubt, played a great part in preventing its solution in the past; unfortunately, it would not be far from the truth to say that they operate as powerfully to-day. Taking Italy as a whole, the area of the malarious districts is so great that the question of their restoration to a healthy and habitable state may well be regarded as national; but, on the most moderate estimate, the carrying out of anything like a comprehensive scheme of sanitation would involve a far greater expenditure of money than the already heavily strained resources of the country could provide; and this has even proved a stumbling-block to the various attempts which have been made to deal with that small portion of it which is comprised within the limits of the province of Rome.

Schemes for the drainage and reclamation of the Roman

Campagna have been put forward without number, all of them involving a more or less enormous capital expenditure, and thus far, perhaps fortunately, none of them have been carried out. The immediate benefit to be derived from colossal engineering works is more than doubtful, and their promoters have, in the author's opinion, uniformly failed to recognise the undoubted fact that, in the cure of a malarious country, nature will have her "say," and that far more is to be hoped from the slow but constant working of natural processes, judiciously directed, than from any mere drainage scheme, however vast and however ably carried out. If, instead of passing one Act after another directed to such ends as these, the Italian Parliament had realised that precious years were slipping by in which trees might have been quietly growing, small areas attacked and mastered in detail, the limits of existing healthy areas slowly but surely increased, and fresh oases created in the midst of a pestilent wilderness, much might have been done to serve as a basis for future operations on a larger scale, when the means should be forthcoming for carrying them out. Behind any scheme for the reclamation of the Campagna lies the ever-recurring question of "Rimboschimento," or the re-afforesting of the surrounding hill-country, whose ill-regulated drainage is largely responsible for the water-logged condition of the subsoil of the lowlands. Legislation on the subject finds a very prominent place in the Italian statute book, but it appears to be of no avail. Trees will not plant themselves, nor will mere legislative enactments, however stringent, take the place of intelligent husbandry; and, until the cultivators of the soil can be brought to see for themselves that a tree may serve some other purpose than firewood, there is but little hope that the spurs of the Apennines will again be clothed with woods, as they were in the times of the Cæsars. There is no disease so thoroughly bound up with local conditions as malaria, none which can be so surely eradicated by patient and unremitting toil. Some of the larger areas will, undoubtedly, require the help of the State in order to bring them under control, but, until that help shall be forthcoming, much may

be done by small communities and even by individuals, and not a little has been so done, to enlarge the healthy areas and make life more tolerable in those less fortunately situate.

The disease has taken centuries to acquire its present sway, and time will be one of the most important agents in dethroning it: the engineer may, and undoubtedly can, do much to shorten the campaign, but, unless his attack be steadily and unceasingly supported by the forester and the husbandman, his labour will be in vain, and possibly even harmful.

CHAPTER XXVIII.

"ROMAN FEVER," SO-CALLED.

"SEE Rome and die," is a saying which appears to have for a very large number of those who visit or intend to visit the eternal city, a double meaning. There is in their minds some vague apprehension of a risk to be run, a danger of acquiring a disease peculiar to the place and known as "Roman fever." So far as the author has been able to discover, no disease bearing this name has ever been described by any medical writer; patient inquiry into the history of cases (?) has yielded absolutely nothing beyond the fact that whatever "Roman Fever" may be, it is, at all events, made to include many acute disorders well known elsewhere, and was, in two instances, unquestionably confounded with typhoid.

The term is unfortunately too well known, and meaningless though it may be to the medical world, it has its terrors, and they are real, for the uninitiated. It has been advisedly chosen as the title of this book, and the discussion of it relegated to the concluding chapter in the hope that its descent to the limbo of forgotten stupidities may be thereby materially hastened.

Stupid and misleading though the term may be, it must have had an origin, and this is, fortunately, not difficult to discover.

Dismissing at once the idea that there is any disease whatever absolutely peculiar to Rome, we have only to bridge the interval between the tenth century, to which we carried

the history of the growth of malaria in the province of Rome, (Chapter VII.) and the present day, by one or two references, to make it clear that "Roman Fever" is none other than malaria raised to an exalted position because of the importance of the city infested by it. The supposed peculiar unhealthiness of Rome is by no means a modern invention, but has descended to us from very early times, though it has been left for the modern traveller to misunderstand and envelope in a species of mystery the true nature of the disease which he might there acquire.

Peter Damien's verses to Pope Nicholas II., in the eleventh century—

> "Roma vorax hominum, domat ardua colla virorum,
> Roma, ferax febrium, necis est uberrima frugum,
> Romanæ febres stabili sunt jure fideles" *

—unquestionably connect Rome with fever. Passing over the next seven centuries, we find Doni beginning his book † with a lament that though Rome was a magnificent city, full of all that man could desire, and planted in the midst of a fertile country, its healthiness did not correspond with these advantages. There is no mention, however, in his work of any peculiarly Roman disease; on the contrary, he is at some pains to explain that the unhealthiness is due to the prevalence of ague in the suburbs and surrounding country, and he expressly complains that there are many other well-known cities similarly placed in this respect, but that because Rome was a city of such great importance in the eyes of the civilised world its very defects had been exaggerated in like proportion.

Here then is the whole story of the origin of the term "Roman fever" in a nut-shell, and the constant use of the

* Which may be freely translated :—Rome that devours men and bends the necks of the sturdiest, Rome fertile in fevers, abounding in the fruit of death, and to whom by an unalterable law fever is ever faithful.

† *De restituenda salubritate agri Romani.* Florentiæ, MDCLXVII. "Ejus tamen salubritas ad cæteras dotes minime respondeat, immo Romanæ urbis conditio hac ex parte sit plane deploranda."

word "febbre" by the common people, to express almost every disease under the sun, has probably served materially to perpetuate and confirm the superstition. Ignorance of the language, and still greater ignorance of the people and their habits of thought, which but too often characterise the modern traveller, supplies the rest and explains the vague dread under which many labour whilst seeing the sights of Rome.

Though the reader will understand that the phrase "Roman fever" has absolutely no definite meaning whatever, those who use it are generally prepared with several "authentic cases," even of death from the disease, which have come within their knowledge. The author has carefully investigated the history of some five or six cases in which the whole of the facts were accessible, and the cause of death or sickness in every case was found to be typhoid fever, in two cases only complicated by malaria. In no case was there any satisfactory proof that the disease had been acquired in Rome, or even in the immediate neighbourhood, but rather the contrary, the poison having been clearly acquired elsewhere and brought to Rome to develope its effects, the period of residence being too short to allow it to be otherwise.

It is difficult, if not impossible, to trace the place of infection in the case of individuals who are constantly travelling, but we need have little hesitation in asserting that a patient found to be in the second week of typhoid fever a day or two after arrival in Rome, acquired the poison elsewhere.

It is not one of the objects of this book to prove that Rome is exceptionally free from typhoid fever, but it may be of interest to know the position of Rome in this respect in comparison with other cities.

In a paper* communicated to the International Medical Congress of London, 1881, Prof. Toscani gives a table showing the deaths from typhoid and typhus fever per 1,000 inhabitants in some of the principal cities of the world during the three years 1878–80, from which it appears that Rome

* *Bulletino della Commissione speciale d'Igiene del Municipio di Roma*, vol. ii., p. 246.

stands eighteenth on the list, and London twenty-seventh, whilst St. Petersburg heads it with a mortality of 4·86 per 1000.

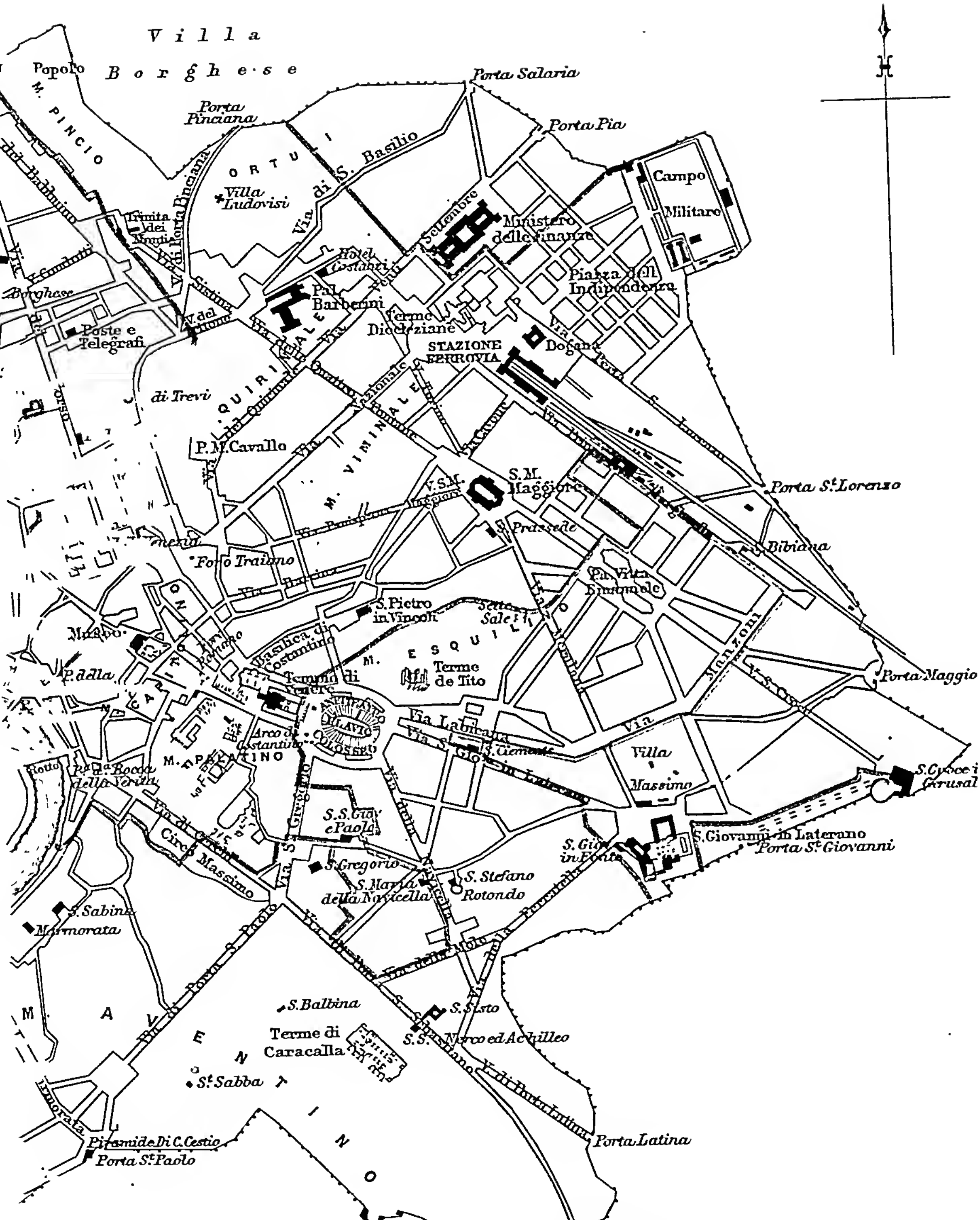
MORTALITY FROM TYPHOID AND TYPHUS FEVER PER 1,000 INHABITANTS.

St. Petersburg	4·86	Bologna	0·80
Bucharest	2·81	Buda-Pesth	0·79
Barcelona	1·80	Venice	0·70
Odessa	1·58	Bâle	0·68
Alexandria	1·33	Paris	0·68
Turin	1·18	Naples	0·67
Leghorn	1·17	Prague	0·57
Milan	0·96	Rome	0·55
Warsaw	0·88	Glasgow	0·54
Baltimore	0·81	Messina	0·48

These figures are given for what they are worth, but they will suffice to show that there are many well-visited cities with a far more evil character for the prevalence of these diseases than Rome; and it must be remembered that during the past ten years the most strenuous efforts have been made to improve the sanitary condition of the city in every respect.

In all malarious countries the physician has to be on his guard against the complication of other well-known diseases by ague. Under these circumstances the symptoms are often puzzling, the temperature curve is unaccountably irregular, and diagnosis may be very difficult until the judicious exhibition of anti-periodic remedies removes the disturbing element and the true nature of the malady becomes at once apparent.

The frequent occurrence of malaria complicating typhoid fever, and certain obstinate forms of enteritis, very prevalent in some of the wet and marshy districts of Italy, is so well recognised that the combination has been termed typho-malaria; whether in all cases the intestinal disorder should be regarded as a separate disease due to a distinct and separate cause is by no means clear. Bad food and water, combined with great poverty and constant exposure to a damp and malarious climate, seems, however, to favour the production of a species of enteritis accompanied by an intermittent fever, which, however mutually interdependent they


Villa Borghese
Popolo
M. Pincio
Porta Pinciana
Porta Salaria
Porta Pia
Ortuli
Villa Ludovisi
Via di S. Basilio
Campo Militare
Ministero delle finanze
Settembre
Hotel Costanzi
Pal. Barberini
Piazza dell Indipendenza
Terme Diocleziane
Stazione Ferrovia
Dogana
Trinita dei Monti
Poste e Telegrafi
di Trevi
Quirinale
P. M. Cavallo
M. Viminale
Via Nazionale
S. M. Maggiore
S. Prassede
Porta St. Lorenzo
Bibiana
Foro Traiano
S. Pietro in Vincoli
Sette Sale
Esquilino
Terme de Tito
Pa. Vitt. Emmanuele
Museo
Basilica di Costantino
Tempio di Venere
Colosseo
Via Labicana
S. Clemente
Arco di Costantino
M. Palatino
Campidoglio
Porta Maggio
Villa Massimo
S. Croce i Girusal
Bocca della Verita
S.S. Giov. e Paolo
S. Giovanni in Laterano
Porta St. Giovanni
S. Gio. in Fonte
Circo Massimo
S. Gregorio
S. Maria della Navicella
S. Stefano Rotondo
S. Sabina
Marmorata
S. Balbina
S. Sisto
S.S. Nereo ed Achilleo
Terme di Caracalla
St. Sabba
Aventino
Piramide Di C. Cestio
Porta St. Paolo
Porta Latina
Porta St. Sebastiano

may be, are best treated as two separate diseases occurring at the same time and in the same person.

Turning once more to intermittent fever, we have to inquire, so far as is possible, into the real nature of the risk of acquiring it incurred by the visitor to Rome.

It has already been shown that the "fever season" in the Campagna begins early in the summer and extends into late autumn. The vast majority of travellers visit Rome between November and April, so that, so far as season of the year is concerned, they practically run no risk at all. It has further been shown that the malaria is anything but uniformly distributed, and when we consider the places most visited, and the conditions under which the visits are made, it will be easily seen that the risks are very small indeed. Risks there may be, but the ordinary sight-seer is rarely, if ever, exposed to them. Small though the chances are of acquiring ague in Rome at this period of the year, it is a matter of wonder that there is not more sickness among visitors than is actually the case. Arriving as they do either after long and wearisome railway journeys, or from other places which have been diligently "done" guide-book in hand, they proceed on the same plan to work through the thousand sights of Rome in three weeks or a month, or even less, spending their time from early morning till late at night in rushing about from one place of interest to another, neglecting meals and all the most ordinary rules of health, and in a state of constant excitement, pursued by the fear that, on the one hand, something has been left unseen which the guide-book says ought to be seen, or, on the other, that they are running a sort of race with death in the guise of "Roman fever."

Quinine may without exaggeration be said to form a not inconsiderable portion of the dietary of such mere sight-seers. Cinchonism is not uncommon, and it is hardly a matter of wonder that many fall ill as the result of strange food, irregular habits, and fatigue, aggravated by the wildest abuse of drugs.

All these troubles are put down to the pestilential air of Rome, and such a visit is remembered in many a family as having ended in "Roman fever."

Those who stay through the summer and explore the Campagna are very few in number, and, as a rule, thoroughly understand the nature of the risks they run; they cannot avoid a more or less intimate acquaintance with ague, either in their own bodies or those of others, and, so far from regarding Rome as a place to be avoided on this score, soon learn that they are at least as safe, if not safer, from the disease within its walls than outside.

There is one question of great importance still left for consideration, and that is the water supply of the city, and its relation to the distribution of malaria within it.

The belief that the poison of malaria is water-borne, and that to drink the water of a malarious district is in some degree to risk infection, is very widely spread, and even finds expression in medical works of some authority. The evidence in support of this opinion consists in the main of a number of well-authenticated cases of so-called "ship malaria." In the author's opinion the proof afforded is very slender indeed, and the circumstances which surround an outbreak of malarial fever are so complicated, and important factors in its production are so very easily overlooked, as to render the "post hoc ergo propter hoc" method of argument entirely inadmissible. Inasmuch as the evidence of "ship malaria" being caused by the drinking water taken on board is almost entirely of this character, it cannot be regarded as in any way conclusive. If there be a particulate malarial poison, and if it be in any sense water-bred or water-borne, Rome should be one of the most malarious cities of the world; that such is not only not the case, but that the distribution of the disease within the walls has absolutely no relation whatever to the sources of water supply, is strong presumptive evidence against any such theory.

The City of Rome is at present supplied with water from four principal sources through four separate aqueducts: these waters are known respectively as the Acqua Paola, Acqua Vergine, Acqua Felice, and Acqua Marcia. The map (Plate XXXIX.) shows sufficiently clearly the water supply of the city, so far as it is derived from the first three of these

sources. The distribution of the Acqua Marcia, the most esteemed of all, is not shown, because its use is increasing so rapidly that any map professing to show it would be out of date almost before it could be printed. As a matter of fact, all the newer quarters are supplied chiefly from this source, and it is making its way even into the older parts of the city.

A comparison of this map (Plate XXXIX.) with that of Lanzi and Terrigi, showing the distribution of malaria within the city (Plate XXX.), will suffice to show that so far, at all events, as Rome is concerned, water supply and malaria stand in no sort of relation to one another, and, were it not that attempts have been made to demonstrate the contrary, any further discussion of the question would be quite unnecessary. It may, however, be useful to state concisely the source of these waters, the total amount of each which enters the city daily, their average chemical composition, and the reputation of the localities in which they arise as regards malaria.

ACQUA VERGINE.

The first water supply brought to Rome on any considerable scale, after the destruction of the ancient aqueducts, consisted in the restoration of the Acqua Vergine, designed by Pope Paul III., and carried out by Pius IV. and Pius V., and completed in the year 1570. The springs which form the headwaters of the Acqua Vergine arise in marshy soil, near Salone, at the eighth milestone on the Via Collatina.* The locality is uninhabited and uninhabitable in summer and autumn by reason of the malaria, and is barely eighty-five feet above sea level. The aqueduct runs underground through the greater part of its course, and though the water always has been, and still is, held in very high esteem by the Romans, the differences of composition which are found to exist between samples taken at the source and samples taken in Rome itself are such as to support the possibility that pollution by subsoil drainage takes place en route. The

* *Frontinus de Aquaeductibus Urbis Romae*, Lib. I.

total length of the aqueduct is nineteen kilometres from the source to the Pincian Hill, where it divides into two to serve the lower parts of the city. Its course within the walls is fairly marked by the following fountains:—Piazza Colonna, P. della Rotonda, Campo dei Fiori, P. Navona, P. della Scrofa, P. del Babuino, P. Venezia, P. di Ripetta, P. della Barcaccia, P. del Popolo, and that by which it is best known, the fountains of the Piazza di Trevi. The daily quantity of water supplied to the city by this aqueduct is about 155,271 cubic metres.*

ACQUA FELICE.

The Acqua Felice has its source in a number of springs about fourteen miles from Rome, near the site of the ancient Gabii, a little to the north of the town of Colonna. These springs, the neighbourhood of which is peculiarly malarious, are spread over a considerable area at varying heights above sea level, some being as much as 325 feet, whilst the head of the aqueduct is but 212 feet above the datum line. They originally supplied the Aqua Alexandrina constructed about A.D. 226 by Severus Alexander, the last built of the Roman aqueducts.

The project for restoring this aqueduct and bringing the water once more to Rome originated under Pope Gregory XIII., but he dying before the work was begun it was left to his successor, Sixtus V., to undertake and complete the work, which he did at an enormous expense, making use to a large extent of the ruins of the Aqua Claudia for the purpose. The new aqueduct was opened in Rome on June 15, 1587. It is 32·592 kilometres in length, of which 22·222 are below ground, and 10·370 carried on arches. The distribution of the water within the City may be gathered from the fact that it supplies the following public fountains: Piazza di Termini, Quattro Fontane, Ara Cœli, Campitelli,

* *Sulle acque della moderna Roma e sui metodi usati nella distribuzione di ess pei pubblici e pei privati comodi della popolazione*, Prof. Nicola Cavalieri San-Bertold. Roma, tipografi Ajani, 1859.

Madonna dei Monti, San Giovanni in Laterano, and others outside the walls at Porta Furba, Porta San Lorenzo, and one near the Porta Maggiore. Subsequently the water was made to supply fountains at the Villa Medici, S. Maria Maggiore, the Tritone in the Piazza Barberini, Bocca della Verita, Monte Cavallo, Piazza San Clemente, Campidoglio, Tartaruga, Piazza Guidea, and P. Montanara.

Further sources of supply have from time to time been added to the original head-waters, and the total quantity carried by the aqueduct is now estimated at 21,632 met. cub. daily.

The water is of good quality, but very hard, carrying such quantities of lime as to obstruct the service-pipes very frequently.

ACQUA PAOLA.

The Acqua Paola is a restoration of the Aqua Trajana constructed by the Emperor Trajan, A.D. 109. It arises in a number of somewhat widely separated springs in the neighbourhood of the Lago di Bracciano, supplemented by a supply from the lake itself. These springs vary in height from 1,290 to about 1,000 feet above sea level, the surface of the lake having an elevation of 520 feet. The present aqueduct is fifty-two kilometres in length, and was originally restored and reconstructed by Pope Paul V., in the year 1611, various additions to the sources of supply being made by his successors up to the year 1675, when the lake was tapped. The Acqua Paola supplies the whole of the Transtiberine district.

As at first brought to Rome by the Pope whose name it bears, the water was probably of fair quality, but this has been seriously lowered by the throwing into it of the waters of the Lago di Bracciano and the Lago di Martignano. The temperature is very variable, and the water is frequently turbid, and, in summer, acquires a distinct taste and odour from contained vegetable matter; for these reasons the Acqua Paola cannot be regarded as a satisfactory water.

The district in which it arises is as a whole malarious, some portions of it particularly so. The total quantity brought to the City daily by the aqueduct is estimated at 80,870 met. cub.

ACQUA MARCIA.

The head-waters of the Acqua Marcia are formed by certain lakes near the town of Arsoli, close to the road (Via Sublacensis) between Tivoli and Subiaco, in the valley of the Anio, about seven English miles below the latter place. These lakes are fed by innumerable small streams from the hills which lie to the northward, their general level being about 1,000 feet above the sea.

The original Marcian aqueduct was built by the praetor Q. Marcius Rex by order of the Senate B.C. 144. The present supply is under the control of a company, and is carried by an aqueduct fifty-three kilometres in length, of which about one-half is built upon arches above ground, the remainder consisting of iron pipes laid below the surface. The work was opened for public use on September 10, 1870. A little below Tivoli, at 184 metres or about 570 feet above sea level, the water enters the iron pipes which convey it to Rome, under sufficient pressure to raise it to the tops of the highest houses in the City. The total daily quantity delivered is about 30,000 met. cub., and this can easily be doubled by laying another main.

The water is of excellent quality, but contains a very large quantity of lime salts, which are readily deposited and give great trouble by blocking the service pipes. The temperature is exceedingly constant, varying but little from 11° C. (51·8° F.)

The Acqua Marcia is highly prized by the Romans, and is rapidly making its way into all parts of the city. The neighbourhood of the head-waters is malarious.

CHEMICAL COMPOSITION OF THE WATER SUPPLY OF ROME.*

	Acqua Vergine.	Acqua Felice.	Acqua Paola.	Acqua Marcia.
Solid residue in 100,000 parts at 100° C.	37·24	44·80	29·00	29·64
Solid residue in 100,000 parts at 180° C.	36·92	43·84	27·80	28·60
Total hardness in French degrees. . .	18·33	29·36	11·8	27·52
Permanent hardness in French degrees	2·60	2·47	2·86	6·57
Temporary hardness in French degrees	15·73	26·89	8·94	20·95
Dissolved oxygen in 1 litre	5 c.c.	18 c.c.	7 c.c.	7 c.c.
Dissolved nitrogen in 1 litre	16 c.c.		12 c.c.	14 c.c.
Total, CO_2	24·53	31·52	14·38	25·35
In 100,000 parts of water.				
Sodium chloride, NaCl	2·114	1·649	6·146	0·643
Sodium carbonate, Na_2CO_3	4·318	2·535	2·961	0·186
Potassium nitrate, KNO_3	1·547	1·153	0·436	0·429
Potassium Carbonate, K_2CO_3 . . .	4·586	3·337	4·223	—
Calcium Sulphate, $CaSO_4$	2·890	3·461	3·552	0·449
Calcium nitrate, $Ca(NO_3)_2$	—	—	—	0·074
Calcium carbonate, $CaCO_3$	13·090	21·955	4·371	19·270
Magnesium carbonate, $MgCO_3$ . .	3·920	5·817	3·898	6·888
Silica, SiO_2	4·360	4·360	1·625	0·680
Total Inorganic Solids	36·825	44·267	27·212	28·619

The water supply of Rome may be estimated approximately to be as follows:—

Acqua Vergine . .	65,000	met. cub. per diem
Acqua Paola . . .	80,000	" " " "
Acqua Felice . .	20,500	" " " "
Acqua Marcia . .	30,000	" " " "
Total .	195,500	met. cub.

Or about 800 litres per head of population per diem (nearly 200 gallons) all of most excellent quality if we except the Acqua Paola.

* The above analytical details are taken from "Analisi chimica delle acque potabili della città di Roma, eseguita, per incarico del municipio dal Prof. Francesco Mauro, e dai dottori Raffaello Nasini e Augusto Piccini, diretto dal Prof. Stanislao Canizzaro." Roma, tipografia fratelli Bencini, 1884

If it be possible for such large volumes of water to carry any malarial poison at all, the area supplied by the Acqua Vergine (Trevi) ought to be the most affected, as the aqueduct is the shortest, and the site of the head-waters the most malarious. As a matter of fact, there is, perhaps, no part of Rome so generally free from the disease. The question, so far at all events as Rome is concerned, is indeed not worth further discussion, as it has been abundantly proved that the distribution of malaria within the walls is strictly governed by density of buildings and population.

It may appear unnecessary to demonstrate that the Roman water supply is above suspicion as a source of malarial infection; the enormous quantity of water and the distance travelled being probably sufficient to account for the destruction of any possible number of organisms. Nevertheless there are those who hold that, inasmuch as the head-waters of these aqueducts all arise in malarious localities, there is a danger of infection by this means; it is therefore perhaps well to place the facts on record, and leave them to speak for themselves.

There still remains the question, Is the local water (if one may so term it) of a malarious country capable of carrying infection? Proof of this is absolutely wanting. Ague-stricken districts generally abound in stagnant waters which from every point of view are unsuitable for drinking purposes, but there is no proof whatever that the water of springs and running streams, however malarious their immediate neighbourhood may be, is a source of infection, and such evidence as there is on this point worth considering is entirely against the theory that the poison of malaria, if such there be, is water-bred or water-borne. Were this the case, despite the overshadowing influence of other conditions, some proof would be forthcoming that, in a generally malarious country, the better the water supply the less the malaria. There is no evidence in this direction whatever, and we are abundantly justified in assuming, so far as our present knowledge goes, that the disease cannot be acquired through water.

CONCLUSION.

The tendency of pathological research in the present day is to trace, or seek to trace, the origin of disease to the operation of specific pathogenic organisms, and it cannot be denied that the results obtained justify the assumption in a large number of instances. The author is fully aware that his attempt to show that, with regard to intermittent fever at all events, the interference of a pathogenic organism is not only not proven but is unnecessary in order to account for the phenomena of the disease, is not likely to meet with general acceptance from those best qualified to form an opinion. Nevertheless, he would urge that the break-down of delicate and complicated machinery under strain such as that to which the heat-regulating mechanism of the body is unquestionably subjected in malarious countries is not impossible, but on the contrary extremely probable. The views set forth in the preceding pages are not those with which he entered upon the inquiry; on the contrary, they represent the effect produced by daily contact with the disease and the conditions under which it might be acquired, and were adopted reluctantly in the place of a more generally accepted theory.

The reasons which led to this change of opinion in the face of much apparent evidence in support of the theory of a pathogenic organism have been fully set forth in these pages, and have not been so stated without the fullest and most careful consideration. They have no claim to absolute novelty, but are rather an elaboration of similar theories which have been formulated by others. The evidence in favour of the "Chill Theory" as stated by Oldham, for example, is undoubtedly not conclusive, as it amounts to little more than an assertion supported by certain broad facts.

The author trusts that these facts have received amplification, and that their connection with the disease has been rendered closer as the results of his labours. It may be that

the peculiar local circumstances which have been detailed and the extraordinary connection which unquestionably exists between the disease and local meteorological conditions are after all only unwitting contributions to the life-history of an organism as yet undiscovered; but, whatever the actual cause of the disease may eventually be found to be, these facts will need to be taken into account and made to harmonise with future discoveries. They are in the author's humble opinion the constants of the problem; the variable as yet is the supposed micro-organism, which, though so widely diffused that the greater part of mankind is known to suffer from its supposed operation, has never yet been discovered either in the air he breathes, the water he drinks, or the earth he treads upon, the researches of many patient and competent observers notwithstanding.

The direct evidence as to the existence of such an organism and its connection with the disease is shadowy in the extreme. Extraordinary, but by no means constant, changes in the blood corpuscles have been shown to take place, but it has not yet been shown that they are inconsistent with the hypothesis of causes acting from within, and despite all that has been done in this direction proof that these strange bodies are in *all* cases anything more than modified blood corpuscles, or that they are even invariably present, is still wanting.

Nothing has yet been discovered which at all approaches in clearness the connection of the Anthrax bacillus with the various forms of disease with which it is associated. In this case the life-history of the bacillus and its mode of entry into the animal organism is well known, and, whatever our ignorance of its precise mode of action may be, we are able to assert that without the intervention of the bacillus the well-known symptoms would not arise.

How different is the case of the supposed origin of malarial fever in a pathogenic organism! No less than fourteen biologically distinct organisms have been severally described as the cause of the disease. Improved methods of research and the known skill of its discoverers have given the last candidate for the office of producer of intermittent fever a much stronger

position than any of its predecessors, but the proof of its alleged disease-producing power is still wanting.

The one characteristic of intermittent fever, intermission of temperature, is notoriously a natural property of the human organism, an exaggeration of which will account for all the thermic phenomena of the disease. It is after all but natural to examine how far it is possible for the disease to originate "at home" before seeking for an external cause, for, granted that an organism entering the body from without be the cause of the rhythmic aberration of bodily temperature, *the* characteristic phenomenon of malarial fever, we are still without an explanation of *how* these aberrations are brought about. The one merit of the theory propounded, if it have any at all, is that it not only explains the origin of the disease, but to a very large extent accounts for its most important phenomena and the mode of action of remedies known to be of value.

The animal organism is complicated in the extreme, and to suppose that it is beyond the reach of the physical conditions to which it is subjected, and to require a "deus ex machinâ" in the shape of some lowly form of life to account for its diseases in every case, is surely irrational.

The possibility of complicated mechanism breaking down under strain can hardly be denied; the question at issue in this particular case is whether it be more likely that the phenomena of intermittent fever should be the result of such inherent liability to break down or of the operation of some specific organism coming from without. This may be a new and, in the present state of our knowledge, a wrong view to take of the origin of disease, but it is one which in the author's opinion requires careful consideration, and it is not to be summarily rejected because it does not fit with prevailing ideas. Be the cause of malaria what it may, the author earnestly hopes that the facts recorded in these pages, though in the light of further knowledge they may bear a different interpretation from that put upon them, may be of service to those who may hereafter turn their attention to this subject.

INDEX.

INDEX.

F.

S.

T.

U.

V.

W.

Z.

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NOTE.—Plates XXXII. and XXXIII. These Plates should have been acknowledged in the text, pp. 225 and 226, as "after Prof. Silvestrini."

THE END